Beyond Rare Earths: Dual-Track Governance in China's Critical Minerals Strategy for Semiconductors and Clean Energy, 2010-2025

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While non-rare-earth minerals including graphite, germanium, and gallium are central to the energy transition and semiconductor manufacturing, they sit in fragmented regimes and have received little academic attention. The work described here presents the case that China's approach to these minerals can be characterized as a dual-track governance strategy: (1) governance-by-chokepoint, encompassing precision export licensing that turns midstream dominance into leverage, and (2) governance-by-institution, where Beijing uses BRI-style finance and standards to stabilize and legitimize China-centric supply chain reconfiguration. Using a dataset with partner-level trade flows from 2018 to 2024, this study provides a rigorous set of event-study evidence on the first track. This analysis reveals that Beijing employs a bifurcated strategy. Gallium controls act as a means of rent extraction, as adversaries are forced to pay a significant price premium and trade is rerouted through intermediaries. Graphite controls act instead as a geopolitical filter, where China severs supply to G7 competitors while redirecting volumes to strategic partners like Iran and Indonesia. These findings, in addition to challenging the simple embargo narrative, suggest that in order maximize structural power, China uses granular licensing as a means of reconfiguring global supply chains into a politically indexed hub-and-spoke system.

I. INTRODUCTION AND BACKGROUND

A. EVs, semiconductors, and China's mineral hegemony

Fifteen years ago, the maximum range for an electric vehicle commercially available in the United Stated was under 100 miles, while today many models boast ranges upwards of 500 miles[1]. This development is a story of scientific achievement and engineering breakthroughs, but it is also a geopolitical story. Break open most EV batteries on the market today, and you'll find a $50-100$ kg graphite anode[2], 92% of which is produced in China's anode supply chain. And while each new generation of batteries has seen major changes to cathode design, each chemistry has remained tethered to Chinese-controlled nodes in the critical-minerals system. Roughly 60% of all nickel is now mined in Indonesia with the majority controlled by just two Chinese firms[3], cobalt is 74% mined in the DRC but almost entirely refined in China[4], and lithium is mined chiefly in Australia, Chile, and China yet more than 60% of refining occurs in China[5].

The power-electronics stack increasingly leans on gallium (for GaN) and germanium, and China controls about 99% of primary gallium production and more than 60% of refined germanium production[6]. These minerals and the problem of Chinese control over the supply chain are not limited to battery production. Indeed, the global energy transition and semiconductor manufacturing hinge on a set of non-rare-earth critical minerals — lithium, cobalt, nickel, gallium, germanium, graphite — over which China exerts outsized influence across mining, processing, and governance. Thus, while on the surface a technical story about materials and manufacturing, this is also an governance and geoeconomic story that leads us to ask who sets the rules that structure this dependence and how that structural position is used strategically.

B. Empirical puzzle

There have been significant scholarly and policy debates on rare earth elements (REE), particularly in the context of the 2010 Chinese embargo against Japan[7]. The REE episode is now viewed as the canonical case for debates centered on weaponized interdependence, coercive leverage, and vulnerabilities tied to concentrated supply. While this article will draw on that body of research as source of both inspiration and comparison, it focused instead on non-REE minerals, which are unique in that they are crucial to decarbonization and advanced manufacturing efforts but lie in more fragmented regimes and are relatively understudied in the field.

In the domain of non-REE critical minerals, China's recent behavior is fairly puzzling. On one hand, Beijing has targeted midstream chokepoints with the introduction of increasingly granular export controls and licensing requirements. In July 2023, it pushed through new licensing for gallium and germanium products effective that August[8], which were followed in December of that year by further licensing for graphite-anode materials[9]. Simultaneously, seemingly in an attempt to limit U.S. efforts to reduce reliance on China's manufacturing stack, Beijing supplemented their materials licensing measures with targeted restrictions focused specifically on extraction and processing technology[10]. Most of these restrictions were not walked back until the meeting between Xi Jinping and Donald Trump at the end of October 2025[11].

On the other hand, China has focused on presenting itself as a responsible creator of order in critical minerals. The China Chamber of Commerce of Metals, Minerals and Chemicals (CCCMC) has issued due-diligence guidelines that are clearly modeled in part on the frameworks from the Organization for Economic Co-operation and Development (OECD), signaling both autonomy and degree of isomorphism in norm diffusion[12]. Both the Green Belt and Road agenda and the

2022 joint Ministry of Commerce (MOFCOM) and Ministry of Ecology and Environment (MEE) guidelines on ecological and environmental protection for outbound investment work to explicitly align Chinese finance with community consultation, ecological due diligence, and host country law[13,14]. In this way, in both its rhetoric and increasingly in formal documents, Beijing seeks to depict its firms as stewards of sustainable development while presenting its outbound finance as a means of achieving a greener, more orderly globalization.

When viewed in tandem, these two sides of Chinese policy vis-a-vis non-REE critical minerals create the empirical puzzle of this article. How then should we make sense of a state that is simultaneously using precise export controls on gallium, germanium, and graphite in a way that resembles a system of coercive governance via chokepoints, while also promulgating Green BRI, MOFCOM–MEE environmental guidelines, and CCCMC due-diligence frameworks that both emulate and rival Western standards? Rather than viewing these export controls as merely episodic bouts of retaliation in the context of otherwise cooperative governance, this article argues that this combination of controls (Track 1) and standards (Track 2) are better seen as a coherent strategy to shape order.

C. Research question

This article addresses this puzzle by asking how China uses export controls on gallium, germanium, and graphite to shift the fundamental structure of global non-REE mineral trade. After answering these questions, I then analyze what this reveals about the efficacy of midstream supply chain bottleneck as tools of statecraft as well as China's role in an international order that is increasingly plural and issue-specific.

To better answer this over arching question, this question and resulting analysis is broken down into two sub-questions, and the empirical focus of this work is placed on the first:

- **Export controls and trade reconfiguration (Track 1):** In what ways do Chinese export controls and licensing measures on gallium, germanium, graphite and related technologies serve to reconfigure patterns of trade? Do they simply depress volumes, or do they also induce partner switching, rerouting through third countries, and specification creep that allows for the relocation of chokepoints from raw materials to a narrowly defined set of intermediates?

- **Institutional context (Track 2):** How does Beijing ensure that these coercive measures interact with the broader landscape of BRI-style bundles to entrench PRC-aligned norms and flows?

D. Argument in brief

The central claim of this article is that China has a dual-track governance strategy in non-REE critical minerals, focused less on one-off coercion than on durable order-shaping.

> **Track 1 — governance-by-chokepoint:** In the first mode, Beijing makes use of precision export controls and licensing regimes to use midstream chokepoints as bargaining leverage. In thin value chains like gallium, germanium, and advanced graphite anode materials, China's production dominance becomes a form a structural power by way of technology controls, product-level specifications, and granular licensing.

> **Track 2 — governance-by-institution:** In the second mode, China creates institutional frameworks that it then diffuses to urge firms and partner governments into norms preferred by the PRC. BRI-era finance packages, CCCMC due-diligence guidance, Green BRI principles, MOFCOM–MEE environmental guidelines, and other related standards documents together make up a governance structure that is outward facing by design. These instruments use ESG language to build packaged contract design, permitting practices, and offtake arrangements, increasingly interacting with Western club goods like the Minerals Security Partnership (MSP) and Foreign Entity of Concern (FEOC) rules.

This article argues that it is the union of these two tracks, rather than either individually, that serves to transform China's role in this governance sphere. However, while I theorize the necessity of of both tracks, in this article, I focus empirically on Track 1 in order to show how coercion functions within the broader order. I argue that rather than acting as merely ad-hoc retaliation, export controls are the sharp edge of a much larger structural wedge. They highlight and create chokepoints, while the institutional context of Track 2 ensures that the resulting trade rerouting creates durable dependencies rather than simple evasion.

To do this, in **Section 2**, I first review the relevant literature on plural and overlapping orders, modes of geoeconomic and structural power, and soft law, situating the non-REE minerals domain within debates on alternative global orders and weaponized interdependence. This is followed by **Section 3**, which presents a explanation of the theoretical framework of dual-track governance, drawing on work of flexibility empowerment, structural power, and worlds of order to specify the mechanisms of each track and derive observable implications for trade rerouting, specification drift, offtake lock-in, and institutional feedbacks.

Section 4 provides a detailed accounting of the event study of Chinese export controls on gallium, germanium, and graphite used to characterize China's actions within the Track 1 framework. The empirical findings from this work are presented in **Section 5**, showing the reconfiguration of trade patterns by export controls (Track 1) succeeds as it forces other countries into the institutional pathways defined by Track 2. I conclude in **Section 6**, exploring the implications for both IR theory and policy.

II. LITERATURE REVIEW

A. From world order to material statecraft

While traditional frameworks of order have argued for single-hub models, recent work urges a move towards an environment of overlapping, issue-specific regimes. Johnston's debate on worlds of order posits that rather than pursuing an overarching hegemonic architecture, great powers tend to seek nested, domain-specific orders[15]. This view fits well with the minerals domain made up of the overlapping but distinct systems of trade, standards, export controls, and development finance.

Economy reinforces this in her account of China's alternative order, arguing that Beijing uses institutional bricolage from standards setting to development lending to avoid frontal confrontation while securing strategic advantages[16]. Other authors complement this view of a blended Chinese power strategy, highlighting the deep pluralism in global order[17], the flexibility-empowerment nexus that enables rising powers to leverage informal club-like arrangements[18], and the ability of states to shpe markes via rules, standards and chokepoints as a structural power[19]. When taken together, these frameworks indicate a logic within the minerals regime where advantage comes not from monopolization alone but also a systemized approach to rules configuration exercised by

embedding standards, export-licensing regimes, and concessional finance into the supply chain to create lock-in, veto points and path dependencies. This motivates an empirical inquiry into how China mixes rule-making and rule-exploiting in the non-REE critical mineral supply chain.

When taken together, these frameworks allow us to build a conception foundation for analyzing advantage accrual within the domain of mineral extraction and production. China achieves dominance through near monopoly on production paired delicately with rule configuration, working a preferred set of standards, licensing regimes, and concessional finance into the system of the supply chain. This body of research motivates empirical inquiry of China's blending of rule-making and rule-exploiting in non-REE supply chains.

B. Hardening soft law

A second area of research focuses on how soft-law instruments like ESG guidelines, standards, transparency regimes and investment principles now serve as a form of de facto governance in critical minerals.

The cornerstone for firm-level risk management has long been the OECD's Due Diligence Guidance, and it has gradually been expanded beyond conflict minerals to encompass broader ESG and traceability expectations[20]. The China Chamber of Commerce of Metals, Minerals and Chemicals (CCCMC) guidelines mirror this, adapting the template to firms and value chain realities relevant to China, signaling both autonomy as well as isomorphism in norm diffusion[12].

Standards often act as the central vector geoeconomic power. For most of the 20th and early 21st centuries, the U.S. dominated this game, but China appears to be taking steps to encroach on this hegemony[21]. In a concrete manifestation of this, China's Green BRI and the 2022 MOFCOM-MEE environmental guidelines align outward investment with ecological due diligence, community consultation, and host-country law[13,14].

In parallel, Western initiatives harden soft law into club goods. While OECD and CCCMC guidelines constrain themselves primarily to focusing on transparency and ESG aspects of governance, the Minerals Security Partnership — a coalition of 14 countries and the European Union working to secure supply chains for critical minerals — articulates an explicit intent to coordinate public finance and standards[22]. The U.S. has started the process of codifying market access constraints through the relatively new and unique Foreign Entity of Concern (FEOC) rules, operationalizing geopolitical screening within clean energy tax credits[23]. Technical assessments from the International Energy Agency (IEA) provide a synthesis of these governance moves with market structure, indicating that refining concentration rather than mining is the binding risk to supply chains[24,25].

In practice, these soft-law instruments function primarily as sources of strategic legitimation and as reference points in contract and permitting disputes. Academic work has not suitably answered the question of how voluntary frameworks like Green-BRI and MOFCOM-MEE interact with binding subsidy and trade rules as well as with Western due diligence statutes to produce either standards convergence, mutual recognition, or competitive fragmentation.

C. Concentration and chokepoints

A third set of scholarship is used as the quantitative baseline for assessing the structure of the global minerals market and indentifying the location of chokepoints.

There are three canonical sources for process-level baselines. 1) The IEA's Global Critical Minerals Outlook 2025 provides quantified demand trajectories and concentration metrics at each step in the process from mining to refining, allowing for documentation of persistent trends like China's dominance in lithium chemicals ($\sim$ 70% global output) and rising Indonesian primacy in nickel, even as ex-China refining projects grow from a low base[26]. 2) The USGS Mineral Commodity Summaries and accompanying technical reports provide series that satisfy the requirements of being long-run, country-level, and process-level necessary to anchor any original indicator work[27,28]. 3) Industry data, like Benchmark Mineral Intelligence, helps to clarify bottlenecks in the supply chain. For example, a Benchmark minerals report estimates that roughly 75% of the graphite anode supply chain sits in China, with strong lock-in effects for downstream cell makers[29].

D. Weaponized interdependence and the mechanics of coercion

Previous reviews indicate that China increasingly uses export controls and licensing rules to translate industrial capacity into strategic leverage. To better understand the underlying mechanism of this leverage, this article draws on the theory of weaponized interdependence. While global economic networks were traditionally seen as a means to promote peace, Farrell and Newman argue that these networks naturally centralize into hub-and-spoke topologies[30]. In this framework, if a state controls a key hub, it can exploit the panopticon effect to gather information or chokepoint effects to deny access.

The empirical record as to the effectiveness of chokepoint control is mixed. While the 2010 rare earth embargo would seem the perfect case study for this theory, early studies suggest that markets adapted quickly through a combination of substitution and diversification, which blunted any intended coercive impact[31]. In this manner, China's 2023 restrictions on gallium and germanium are framed as a test of reverse dependence and a probe of Western stockpile and substitution elasticities[32]. Other scholarship on smart sanctions and export controls, however, argues for a more nuanced mechanism. Drezner suggests that rather than seeking broad economic collapse, targeted measures often seek to impose specific costs on adversaries[33].

In the context of China, scholars point to Beijing's strategy of frictional costs, where granular licensing creates administrative uncertainty and thus degrades the competitiveness of an adversary without actually triggering a potentially detrimental full decoupling[34]. Given the small absolute tonnages, USGS characterizes the gallium/germanium value chains as thin, but note the high mission criticality, amplifying the impact of licensing frictions[28]. Beijing's move to require licenses for certain anode materials including graphite introduces a level of administrative uncertainty that can make it hard for non-Chinese offtakers even absent any outright denials[35,36].

Critically for the analysis presented in this study, literature on economic statecraft highlights trade diversion as one of the primary responses to coercion. Work on sanction busters by Early shows that trade is never truly blocked, instead rerouting through "black knight" intermediaries and third-party spoilers seeking to capitalize on the arbitrage opportunity[37]. More recent empirical work by Sheng et al. that focuses specifically on the U.S.-China trade war demonstrates the strategy employed by Chinese exporters of moving down the quality ladder, diverting flows from Western markets to the Global South in order to evade tariffs and restrictions[38]. This body of work suggests that we should expect partner switching following export controls. Instead of stopping trade, granular controls reconfigure it through politically aligned or neutral intermediaries.

E. The institutional backdrop: Strategic bundling

While Beijing employs the Track 1 export controls as coercive levers, the resultant rerouting is only possibly due to a carefully maintained institutional context (Track 2). Studies of China's strategy for Belt and Road Initiative (BRI) investment projects indicate that the country has sought to create bundles of concessional finance, infrastructure contracts, and offtake agreements specifically designed to lock in resource flows[39].

These bundles act as de facto governance regimes. In the DRC, AidData and related governance studies indicate that infrastructure for minerals package deals, loan renegotiations and cancellations, and off balance sheet guarantees have led to more consolidated Chinese commercial control, all the while creating leverage over production schedules and offtake[40]. Likewise, in South America, there is significant cross-validated reportage and industry filings indicating that Chinese firms are scaling stakes across brine and hard-rock projects, pushing these projects forwards through joint-ventures (JVs) that blend capital, processing technology, and guaranteed offtake[3].

Track 2 governance can be thought of as a safety valve of sorts for Chinese strategy. When Track 1 controls cut direct export access to Western adversaries, the Track 2 institutions ensure that this surplus capacity can be absorbed by and routed through friendly jurisdictions like Indonesia or newly aligned hubs in the Global South.

F. Synthesis and researcheable gaps

Across this set of literature, there are two primary unexplored gaps.

The first is the controls-standards interface. How does granular export licensing for graphite or Ga/GaN precursors co-evolve with technical standards and product definitions? This has implications for the relocation of chokepoints from raw materials to intermediate specifications.

The second is the interaction between coercion and rerouting. Existing literature primarily examines the export controls of Track 1 and the BRI finance of Track 2 in isolation, and there is little research bridging the two, explaining how they work as a unified strategy.

This article helps address these gaps by analyzing how licensing regimes reconfigure global flows away from adversaries and into the specific "spokes" cultivated by Chinese statecraft.

III. THEORETICAL APPROACH

A. Critical minerals as a world of order

I posit that China's non-REE minerals strategy is a dual-track governance marked by operation within a plural, domain-specific international order. Per Johnston's world of orders framework, contestation and compliance must be analyzed at the issue level rather than on a single, collapsed verdict on revisionism[15]. Following in this path, I treat critical minerals for semiconductors and clean energy as an institutional subdomain where we can see China acting as both rule-shaper through standards, guidance, and development finance and rule-exploiter through export licensing and domestic industrial policy.

The argument is further structured by two additional strands. First, deep pluralism implies that there exist multiple, non-disjoint governance logics with significant conditions of interdependence[17]. In this kind of setting, rising powers like China seek instruments that maximize issue and governance flexibility in their favor[18]. Second, working off of Strange's framework,

the center of geoeconomic influence in these supply chains is structural power over knowledge and production networks[19]. Control over midstream processing, process know-how, and quality specifications is crucial to this power. Economy's account of an alternative order built from development finance, narrative legitimation, and technical standards provides the large-scale template that this project brings into the minerals domain[16].

When viewed together, these perspectives support the claim that non-REE critical minerals form world of order with distinct rules, players, and playbooks. Instead of abstractly arguing over whether China is a revisionist power or seeking to maintain the status-quo, the task at hand is to explain how Beijing uses export controls, designed standards, and finance plus offtake bundles to directly shape its existence within this subdomain. We can define a parameter space of control methods, which flexibility empowerment suggests Beijing will seek to keep as broad as possible to preserve optionality. Within this space, China charts paths that allow it to toggle between cooperation and pressure as circumstances demand. This instrument space, however, is constrained by the broader environment that it exists in. As deep pluralism implies, Chinese practices here do not simply replace Western frameworks. Rather, they coexist with and often intersect regimes like OECD due diligence, MSP, and FEOC screening.

Within this world of orders, critical minerals for semiconductors and clean energy are a particularly useful subdomain when it comes to inferring the set of methods employed by Beijing. The chains are thin and very specialized, so they are very susceptible to chokepoint politics, yet they are also subject to increasing layers of soft law, ESG guidance, and club-based coordination. The fact that the domain of non-REE critical minerals is both structurally vulnerable and institutionally dense means that they are optimal for observing China's blending of rule-making and rule-exploiting, and the country's use of material statecraft to shape this specific order rather than a single architecture across orders.

B. Defining dual-track governance

a. Core claim. China uses a dual-track strategy in non-rare-earth minerals whereby 1) precision export controls convert midstream chokepoints into bargaining leverage, creating a form of governance-by-chokepoint[32,34,35], while 2) institutionalized outward engagement socializes other countries and firms to PRC-approved norms in sourcing, ESG, and contract design[12–14]. The union of these two tracks is a strategy focused on translating production dominance into durable order-shaping rather than episodic coercion.

I designate this configuration dual-track governance. Many states occasionally use export controls or issue ESG guidelines, but it is rare that the systematically employ both in concerted strategy. China employs these instruments in tandem to pursue a defined direction. One track capitalizes on discrete chokepoints to turn turns structural advantages in processing and technology into leverage. The other track builds and diffuses a set of institutional frameworks that yield normalization of Chinese roles and standards in the same chains.

Dual-track governance builds on Strange's account of structural power[19]. In thin, very specialized supply chains, China's control over production networks, technical knowledge, and quality specifications allow it to leverage markets without depending on visible, continuous coercion. While the mechanisms differ across the tracks, all are grounded in the logic that a small targeted intervention can have an out-sized effect as it works through existing concentrated structures.

b. Track 1: export-control track (governance-by-chokepoint). The set of granular controls and licensing friction that China uses to transform midstream dominance into bargaining leverage define the first track. In analyzing this mode, we should understand export controls as tools of

governance rather than simple bans. Beijing controls the ease of access for foreign firms to critical intermediate inputs such as gallium, germanium, and advanced graphite anode materials with a careful combination of licensing requirements, technology-transfer controls, and finely sliced product definitions.

The specialized and critical nature of the gallium, germanium, and battery-grade graphite supply chains means that very small changes in licensing requirements or product definitions can create significant downstream adjustments. The governance effects of the methods on this track can be seen through three channels:

- **Partner switching —** When facing licensing shocks, importers respond by either rerouting trade through intermediaries or by shifting marginal volumes to alternative suppliers. This then creates new dependencies on specific transit hubs and trading partners even if aggregate volumes stay the same.

- **Specification redefinition —** Chinese authorities can easily move chokepoints from raw materials to processed intermediates by tightening or reclassifying HS codes and technical specifications. Even if other countries develop basic extraction capacity, this specification creep allows China to preserve leverage.

- **Administrative uncertainty —** Uncertainty can be created through delays, documentation demands, and discretionary enforcement. This allows China to structure bargaining, forcing firms and governments to adjust their investment plans and political positions to stay on the right side of relatively opaque licensing practices.

c. Track 2: institutional track (governance-by-institution). The second track is institutional and outward-facing. In order to socialize norms and lock in flows, China uses a combination of joint ventures, BRI finance and policy guidelines like CCCMC due diligence, Green BRI principles, and MOFCOM–MEE environmental guidelines. Beijing is thus able to shape practices around permitting and contracting, push a narrow definition of responsible conduct, and structure risk allocation between host states, Chinese firms, and third parties.

This governance by institution is built on the following:

- **Financing bundle —** China bundles concessional and policy-directed finance with equity stakes, long-term offtake agreements, and occasionally requirements for downstream processing in China to shape the physical direction of mineral flow and the legal and institutional landscape to favor them in the creation of future contracts.

- **Guidelines and soft-law templates —** CCCMC guidelines, Green BRI documents, and MOFCOM–MEE guidance build a unique framework specific to Chinese outbound investment, adapting ESG and due-diligence language but distinct in nature. While formally voluntary, this framework still provides reference points for use in disputes and serves as de-facto standards in the bureaucracy of the host state.

- **Joint ventures and technology partnerships —** China has structured JVs, especially in the DRC and the Lithium Triangle, specifically to combining capital, process know-how, and midstream technology. This allows the JVs to act as a means of diffusing technical standards and business practices aligned with those of China, also serving to shape domestic politics of resource governance by creating local stakeholders that are invested in the success of the Chinese led model.

This set of methods allows for faster initial ramp up, as bundles help move projects more quickly from announcement to production, especially in contexts with limited state capacity. It also creates stickier flows to Chinese refineries, as long-dated offtake clauses and Chinese dominance of refining technology make it harder for host states or other buyers to move from mineral extraction to technology fabrication in a way that avoids Chinese chokepoints.

Employed in tandem, these two tracks allow China to embed leverage in both the material and institutional fabric of the non-REE critical mineral supply chain. Where governance-by-chokepoint constrains the options and costs available to foreign actors at critical nodes, governance-by-institution shapes the surrounding landscape of rules and expectations where those actors plan and negotiate. These mechanisms mean that the abstract ideas of structural power and worlds of order can be observed in trade data and contract structures.

C. Observable implications

Based on this framework, if China is employing a strategy of "Governance-by-Chokepoint" (Track 1) enabled by an institutional backdrop (Track 2), we should observe three specific patterns in the trade data:

1) Partner Switching (The Geopolitical Filter): If, as hypothesized, licensing is used to reconfigure rather than block trade, shocks in export controls should not result in a uniform collapse of exports. Instead, we would expect to see a sharp divergence, where direct flows to adversary nations fall while exports to intermediary or politically aligned jurisdictions grow proportionally. Partner switching should be visible through increased shares through specific Southeast Asian or European countries, even if ultimate consumption remains elsewhere. While aggregate exports may remain non-trivially positive, the destination concentration should rise.

2) Price Discrimination (Rent Extraction): If China seeks leverage, they may allow continued access to dependent adversaries at coercive prices. This means that we should expect a sanctions premium, where the unit value (price per kg) of exports to the adversary bloc rises significantly higher that the price charges to non-aligned partners, reflecting the costs of administrative friction and indirect procurement.

3) Specification Creep (Value Chain Lock-in): If controls are designed to enforce an industrial policy, we should see a marked compositional shift in the trade. Following the implementation of licensing, the hypothesis suggests that the the share of raw material exports (e.g., natural graphite) should collapse, while the share of processed intermediates (e.g., spherical graphite) should rise or remain stable, forcing foreign buyers to remain tethered to China's midstream refining capacity.

D. Alternative explanations

This framework of dual-track governance does not claim that ambitions to shape order drive all variation in Chinese behavior or supply-chain outcomes. Thus we must consider three alternative frameworks:

- **Pure retaliation or coercion —** If export controls have no broader governance ambition and are interpreted as one-off retaliatory moves in response to U.S. or allied actions, we would expect to see short-lived controls, sharp level effects, and limited institutional follow through.

- **Pure resource scarcity —** If Chinese policies are driven entirely by domestic industrial upgrading and resource-security concerns, with any governance effects simply by-products, we should see export controls and finance bundles that are highly sensitive to domestic capacity and industrial policy cycles, but not linked systematically to any outward norm diffusion.

- **Global demand shocks —** It is possible that declines in exports to a specific country are simply indicative of a broader macroeconomic slowdown or cooling demand in the semiconductor and EV sectors. If this were the case, we should see similar declines in non-restricted control commodities (such as aluminum or silicon) exported to the same destinations. A divergence between the "treated" mineral and the "placebo" commodity would rule out this market-based explanation.

IV. RESEARCH DESIGN AND METHODOLOGY

A. Data and HS Code Selection

This work uses high-frequency international trade data to analyze China's critical minerals exports at a granular level. I use monthly export records from the UN Comtrade database from January 2018 through December 2024. As this work is focused on the Track 1 coercive export controls, I first identified a set of HS codes representing the materials of interest. Specifically, as I focus on the two Chinese export control events in 2023, I gather data on gallium/germanium in both elemental and compound forms and natural and refined graphite as well as comparable critical minerals not subject to recent restrictions (used as controls).

Specifically, I track exports under HS6 codes for wrought and unwrought gallium/germanium metal (HS 811292 and 811299) and their compounds (e.g. gallium nitride, arsenide, oxides under HS 285390, 285000, 282590, 282560). Similarly, for graphite, I distinguish natural graphite (HS 250410) from artificial graphite (HS 380110). Lastly, to provide baseline comparisons, I also track polysilicon (HS 280461) and rare earth metals/oxides (e.g. HS 280530, 284690) which were not hit by new export controls at the same time as the studied minerals.

All trade data is harmonized at the 6-digit HS level by truncating any finer product codes to six digits. This was performed primarly to accomodate the fact that the Comtrade public API only allows access to HS6-level data rather than the finer-grained tariff-line data. This allows for internationally consistent categories, but it means that some HS6 lines contain both controlled and uncontrolled commodities, as China institutes export controls at the HS8 level. For example, while HS811292 contains unwrought gallium, which was subject to the export control, in also contains unwrought indium, which was not. This said, overall trends should still be discernible by relative measurement.

B. Grouping and Key Definitions

To properly analyze China's partner-specific export adjustment, I categorize destination countries as either adversaries or intermediaries. While these blocs are fairly subjective, the adversary bloc generally covers the G7 economies and other U.S.-aligned high-tech nations involved in semiconductor sanctions or export control coalitions. These include but are not limited to the United States, Japan, Germany, France, the United Kingdom, Canada, South Korea, the Netherlands, and

Taiwan. In total, the adversary list includes many NATO and EU economies (> 18 countries) and reflects the countries most likely to be targeted by Chinese export controls.

The intermediary bloc, on the other hand, consists of major emerging markets and non-aligned countries that could serve as alternative destinations or transshipment hubs for critical minerals. These are generally either regional manufacturing economies and re-export centers such as Vietnam, Malaysia, Thailand, India, Mexico, Indonesia, Turkey, and Singapore or politically aligned partners or sanction circumvention hubs like Russia, Iran, the UAE, and Kazakhstan. In sum, I identified about 20 such intermediary countries that either have significant electronics/EV industries or geopolitical ties that position them to increase imports from China when Western access is curtailed.

Together, the adversary and intermediary blocs cover the vast majority of China's critical mineral export value, particularly for the commodities that I examine here. This coverage allows me to build a picture of who picks up the slack when others are cut off. For completeness, exports to "Bonded" warehouses and unspecified destinations were recorded, but among the analyzed HS lines, there were no exports of this type during the time period under study.

I aggregate the monthly trade values and volumes for each material category and partner country. As my focus is on export restrictions, I treat China as the exporter and examine its exports to all partners, including trivial re-imports (though these are also zero during this period). For each HS6 code, monthly export value (USD) and quantity (kg) are summed by destination. I then calculate unit values (average price per kg) as a proxy for export prices. While these unit values are interpreted with caution due to quality differences hidden at the HS6 level, they are still very useful for detecting price divergences between country groups. In addition to the overarching mineral categories (Ga/Ge and graphite), the HS6 codes are also mapped to a small number of intuitive subcategories (e.g. "Unwrought Ga/Ge" for raw gallium/germanium metal, vs. "Ga/Ge Compounds" for gallium arsenide, etc.). This merging helps me in analyzing shifts in product mix.

C. Analytical Strategy (Identifying Export Control Effects)

The identification strategy that I employ combines event-study timing with cross-group comparisons to isolate two main consequences of China's export controls. The first is the emergence of a sanctions premium, where we see price discrimination against adversary buyers. The second is trade diversion marked by volume reallocation to alternative markets. As mentioned previously, the export control events that this study concerns itself with are China's imposition of license requirements on gallium/germanium effective August 1, 2023 and on certain graphite products effective December 1, 2023. These dates serve as breakpoints in the time-series. I conduct before/after comparisons at the monthly frequency, primarily using a six-month window on each side of the policy implementation, balancing the need to capture any immediate structural break against the risk of unrelated seasonality or secular trends.

1. Volume (Trade Diversion):

To detect trade diversion, I calculate the change in China's average monthly export volume to each partner before versus after the export control. This means that for each material category I calculate each partner's mean monthly export quantity in the 6-month pre-control period and in the 6-month post-control period, along with the standard error of those means. The difference between

these means (post minus pre) can be seen as the net volume change attributable to the policy shock. I propagate the pre/post standard errors to get a standard error for the volume change (assuming independence). This approach is similar to an event-study difference, but summarized per partner as a single before-after jump. With this data, it is possible to identify significant trade deflection by looking for large positive or negative volume changes relative to their error bounds.

In practice, one would expect China's export licensing to manifest as large negative volume deltas for adversary destinations, potentially offset by positive deltas for some intermediary destinations. I rank partners by the size of their volume change, which allows us to pinpoint the biggest losers and winners from the policy. This is visualized with bar charts of net export change (in millions of kg) with error bars. By aggregating partner-level changes, I also test whether lost volume from adversaries is mostly appearing elsewhere or rather disappearing entirely (the leakage question). Finally, to quantify broad diversion, I aggregate total exports by bloc over time, computing what share of China's exports go to adversaries versus intermediaries each month. A sudden redistribution of those shares at the event date is evidence of geopolitical rerouting.

2. Price (Sanctions Premium):

I investigate price effects by comparing unit values across destination groups. As described above, if China is indeed exploiting its chokehold on supply, I would expect adversary countries to face higher prices after the controls, while intermediaries would see relatively lower prices or at least smaller increases. To track this, I calculate monthly weighted average unit values as total value divided by total kg for each broad category and partner and then aggregate these up to the bloc level for clarity. Using the same 6-month pre/post window, I compute the change in average unit value to each partner and each bloc.

Using this set of data, I then look for systematic differences like an across-the-board upward shift in prices charged to G7 buyers versus stable or even discounted prices for others. To ensure these differences are not driven by outliers or compositional mix, I also examine the export-quantity-weighted interquartile range (IQR) of partner-level prices within each bloc. A widening gap between the adversary bloc's price distribution and the intermediary bloc's distribution post-event would indicate a friendship premium (or conversely, an adversary premium) where China extracts more rent from certain buyers. I graph the top price changes by partner as well, highlighting the most extreme cases of price hikes or drops (with error bars from the standard error of unit values). This complements the bloc-level view by showing, for example, if specific adversary countries were hit with especially steep price increases.

3. Timing and Peer Comparison:

In order to truly understand China's export control, we must center our analysis explicitly on the moment of policy change. To do this, I mark the policy implementation month on all time-series plots (e.g., a vertical dashed line at August 2023 for gallium/germanium and at December 2023 for graphite) and look for any discontinuities at those points.

To bolster causal interpretation, I incorporate placebo tests using unaffected but analogous commodities as controls. Specifically, I perform a comparative event analysis for graphite (treatment) versus polysilicon (controls), as both are polysilicon and graphite are key bulk elements of the critical mineral stack. In the absence of new Chinese restrictions, polysilicon should not exhibit a structural break at end-2023 if the graphite shock is truly policy-driven. Thus it can serve as a true

control.

I construct index series of export volumes for this peer commodity and check that only graphite shows an abnormal post-2023 drop, whereas polysilicon exports follow its prior trend. This difference-in-differences style logic helps rule out confounding global demand swings or seasonal effects, as any common shock would likely affect all industrial exports, not just the targeted minerals.

Similarly, for gallium I compare against rare earth exports as a pseudo-control. Both involve specialized minor metals, but only gallium/germanium were restricted in 2023. However, this cannot be considered a true control, as rare earth exports were subject to various export licensing regimes throughout the period studied from 2018-2024. Nevertheless, as the rare earth export controls did not coincide with the gallium/germanium restriction, we can still analyze the two groups at the time of the control for qualitative comparison.

D. Limitations and Robustness Checks

While my data and design aim for rigor, there are important limitations. First, HS6-level data can mask product heterogeneity. In some cases, a single HS6 code includes multiple related products or elements. As noted above, HS 811292 aggregates gallium and germanium metal with other similar unwrought elements. Therefore, we cannot perfectly distinguish which of the two metals drove any observed change (though both were subject to the same policy and often moved in tandem), nor can we perfectly separate the effect of the controlled commodities from the uncontrolled commodities.

Similarly, when I calculate the unit values at the HS6 level, I am calculating an average prices that might actually reflect different grades or purity levels of a mineral. A spike in unit price could mean higher prices for the same good, but it could also result from a shift to exporting a more valuable specification of the material. I address this in part by examining sub-categories (e.g. separating unwrought vs. wrought gallium, oxide vs. nitride compounds). I also check for specification creep, which is the possibility that China shifted exports to more processed categories to maintain leverage (discussed in results). Even with these measures, the lack of transaction-level price data means that my inference of discriminatory pricing is based on aggregate patterns, not direct contract prices.

The analysis also assumes that official trade data fully capture export flows, which is not an altogether safe assumption. If Chinese producers reacted to the restrictions by quietly diverting sales through clandestine channels, those volumes would not appear in partner import data other than as a net decrease in the total trade volume. This complicates the interpretation of trade diversion. I address this fairly directly by investigating this black hole possibility explicitly in the leakage tests, looking at the rest of world residual. The results confirm that unreported leakage is minimal, as I observe that the category of unspecified destinations remains very small post-control, indicating no large hidden outflows. Thus, while some clandestine or unspecified trade may have occurred, it does not seem to account for a major share of the export declines.

Additionally, I conducted a robustness check for common shocks. As described above, my placebo comparisons with polysilicon and rare earth minerals show no similar drop, which supports the conclusion that the timing and sector-specific nature of the changes I document are driven by China's policy, not by a broad downturn in global demand or other coincident events.

Finally, I acknowledge that my choice of six-month pre/post windows is somewhat arbitrary, but to ensure that my findings aren't sensitive to that choice, I also examined shorter and longer windows and found consistent directional results. The key patterns of a bifurcation in trade flows

and the emergence of price premiums hold under these variations, underscoring the robustness of my conclusions.

Generally, my methodology combines high-frequency data, precise product and country groupings, and before-after comparisons to detect the effects of China's dual-track governance strategy on trade outcomes. By triangulating volume and price changes with multiple comparison groups, I can confidently attribute the observed trade reconfiguration to Beijing's strategic use of export controls.

V. RESULTS AND ANALYSIS

In this section, I present the primary empirically observable outcomes of the coercive export controls that form Track 1 of China's critical minerals strategy: China extracts significant rent from adversaries by means of higher prices, and following export controls, we see significant geopolitical rerouting of material flows to favored partners. Additionally, I find clear evidence of specification creep in the composition of Chinese exports.

Initial comparisons of export behavior for controlled minerals versus their peers as described in the methods reinforce the point that restricted minerals behave differently from unrestricted ones around the crucial dates. These comparisons allow me to draw a number of conclusions from the export data without fear that the results are artifacts of unrelated market dynamics.

In the subsections below, I describe each of these findings and discuss how the data patterns mesh with the theoretical framework of dual-track goverenance presented here.

A. Gallium and Germanium

The gallium and germanium market is primarily composed of three main forms of the minerals: Ga/Ge compounds, wrought metal, and unwrought metal. While all of these forms are key to the semiconductor supply chain, the most valuable and farthest down the chain are the compounds, like GaN, a wide band-gap semiconductor central to modern electronics and energy devices. China exerts a great deal of control over the gallium and germanium market in part because it houses the majority of the processing capability to turn the unwrought elements into wrought forms and process the wrought metals into highly valuable compounds. As seen in Figure 1, these compounds account for 80 to 90% of the value of Chinese exports in this market.

When China enacted export controls on gallium and germanium in August 2023, they targeted Ga/Ge compounds, but protected their control over the supply chain by also restricting the wrought and unwrought metals. As expected, in the months following this control, the total value of these exports dropped significantly. However, the majority of this decline was due to decreases in exports of the compounds, which fell monotonically through the end of the following year. Wrought gallium and germanium exports dropped significantly in the two months after the control, but recovered quickly within 4 months of the control.

The most interesting story, however, is told by the unwrought metals (Figure 2). The post-control rise in exports of the unwrought metals is largely due to panic buying of indium, another critical mineral in the same basket HS6 code, which was not subject to controls, but which investors feared might soon fall prey to a similar plight. This panic buying masked the sharp drop in controlled gallium and germanium. The resultant spike in late 2024, however, was unevenly distributed. While direct exports to the West stayed flat due to strict license denials and de-risking, flows to non-Western partners surged, signaling a rapid rerouting of supply chains where interme-

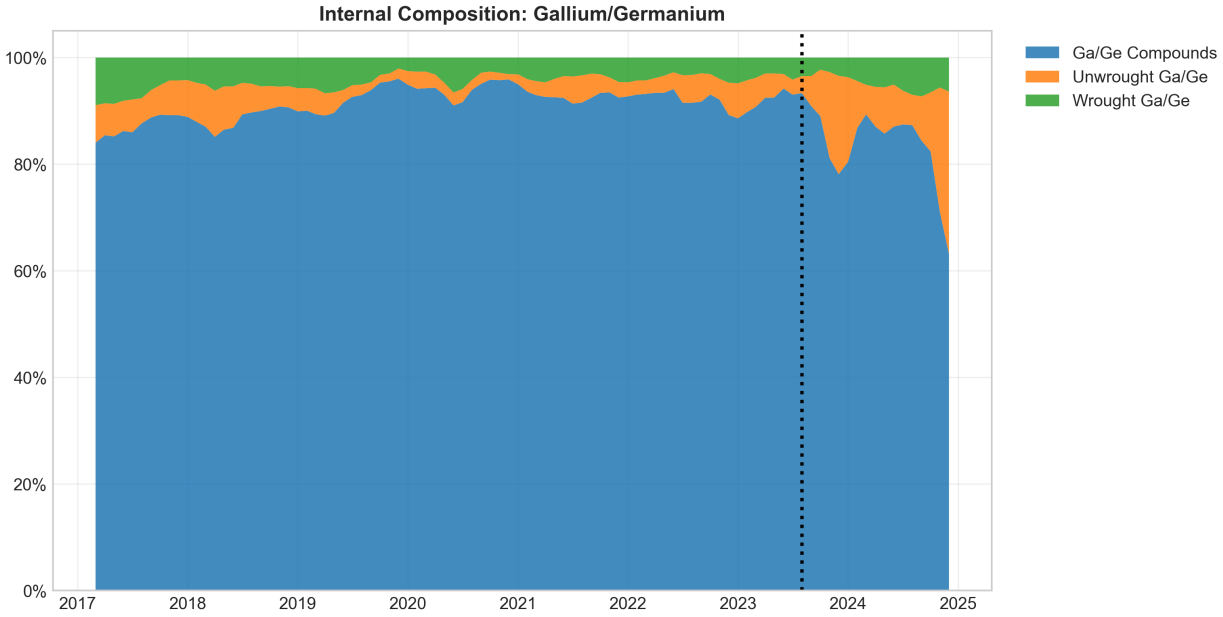

FIG. 1: **Internal Composition of Chinese Gallium/Germanium Exports.** This plot shows the share of value of Chinese exports of these elements belonging to Ga/Ge compounds (blue), unwrought Ga/Ge (orange), and wrought Ga/Ge (green). Historically, compounds represent $80-90\%$ of these exports, but following the August 2023 export control (vertical dashed line), the value of exports of these compounds fell monotonically while exports of wrought metal stayed relatively constant and exports of unwrought metal actually increased.

diaries (such as Hong Kong) were used to bypass restrictions and wash the material for the global market.

The destination patterns for the gallium/germanium sector as a whole are consistent with a re-optimization of supply chains around politically safer nodes rather than a collapse into unobserved trade. In the post-control period, the largest negative shifts in export quantity are seen among technologically salient U.S. partners like South Korea (-2.18M kg/month), Japan (-0.67M), and the Netherlands (-0.29M). On the other hand, the largest positive shifts occur at hubs positioned to intermediate trade, including Hong Kong ($+0.30$M) and Taiwan ($+0.09$M). This pattern is not trade disappearing but rather trade moving to jurisdictions that can repackage, process, or transship, which is exactly what a chokepoint strategy should produce if it is aimed at disciplining adversaries without fully forfeiting export revenue.

The limits put in place on gallium and germanium exports by China enable a form of price discrimination. While it is generally true that Western buyers pay a slight premium on mineral exports, this is greatly exacerbated in the months following these controls, with U.S. allies paying a hefty premium for these critical inputs, effectively transferring rents to Chinese suppliers. This stark difference in unit prices is imminently clear in the data. Prior to the implementation of the license policy, China sold all types of gallium/germanium to adversaries at prices roughly 2 to 3x of the prices for intermediaries, but in after August 2023, when the new licensing regime came into effect, prices for adversary destinations jumped dramatically in a way not mirrored by prices for intermediaries.

On average, G7 importers ended up paying unit prices that were 40 to 50% higher than prior to the control. This premium is well above normal price volatility. In contrast, many friendly or

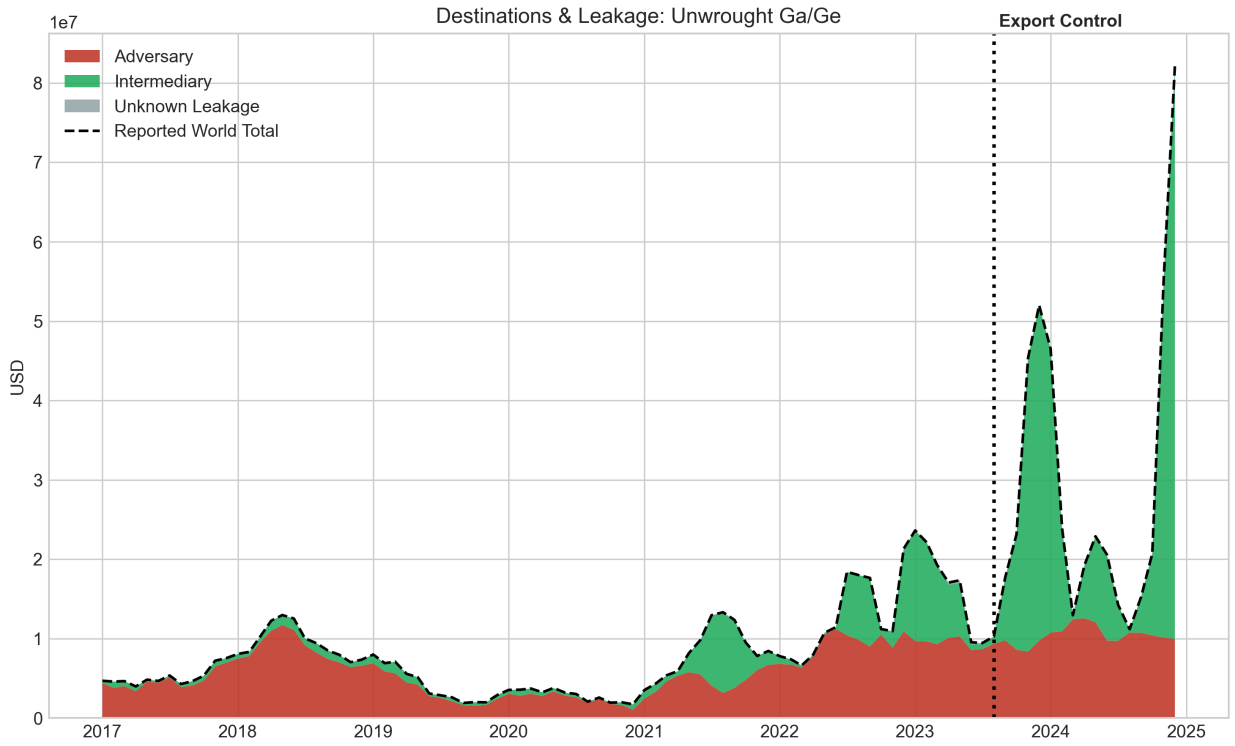

FIG. 2: **Destinations of HS8112.92 Trade** Value of Chinese exports of unwrought metals in the HS8112.92 category in USD before and the August 2023 export control. Y-axis values are in tens of millions of USD. HS8112.92 exports are dominated primarily by indium exports, which were not controlled, but this plot still presents an important trend. In the months following the export control (dashed vertical line), exports of HS8112.92 spiked, driven primarily by investors panic-buying indium in fear of a future control. This spike is dominated by intermediary partners (green), while exports to countries coded as adversaries (red) stayed flat due to strict license denials and de-risking.

neutral importers saw little change in price or even a price decrease following the control. This pattern can be seen clearly in Figure 3, where the price ratio is plotted for gallium and germanium over the 7 years of the study.

As seen in the figure, the price ratio for the peer commodity, rare earths, stays near 1 over the entire period, even during periods where they experienced export controls. On the other hand, the volatility and amplitude of the adversary price premium for the gallium//germanium sector are much larger. While adversaries face a consistent price premium for all forms of the elements, following the relaxation of the export control in mid 2024, the premium for the compounds rose rapidly, as China sought to use the relaxation as a means to resume trade while extracting rent from adversaries.

Importantly to the analysis presented in this study, these wedges can widen even when aggregate sector averages look muted, because HS6 baskets and compositional shifts like the indium-dominance in HS811292 attenuate aggregate price measures. Thus the discriminatory signal is therefore most interpretable in the controlled, higher-value subcategories like wrought and compounds, where licensing hits hardest and substitution is most difficult.

In the post-control regime, one crucial feature is that the price changes are highly destination-specific. This behavior is consistent with discretionary licensing rather than a common global

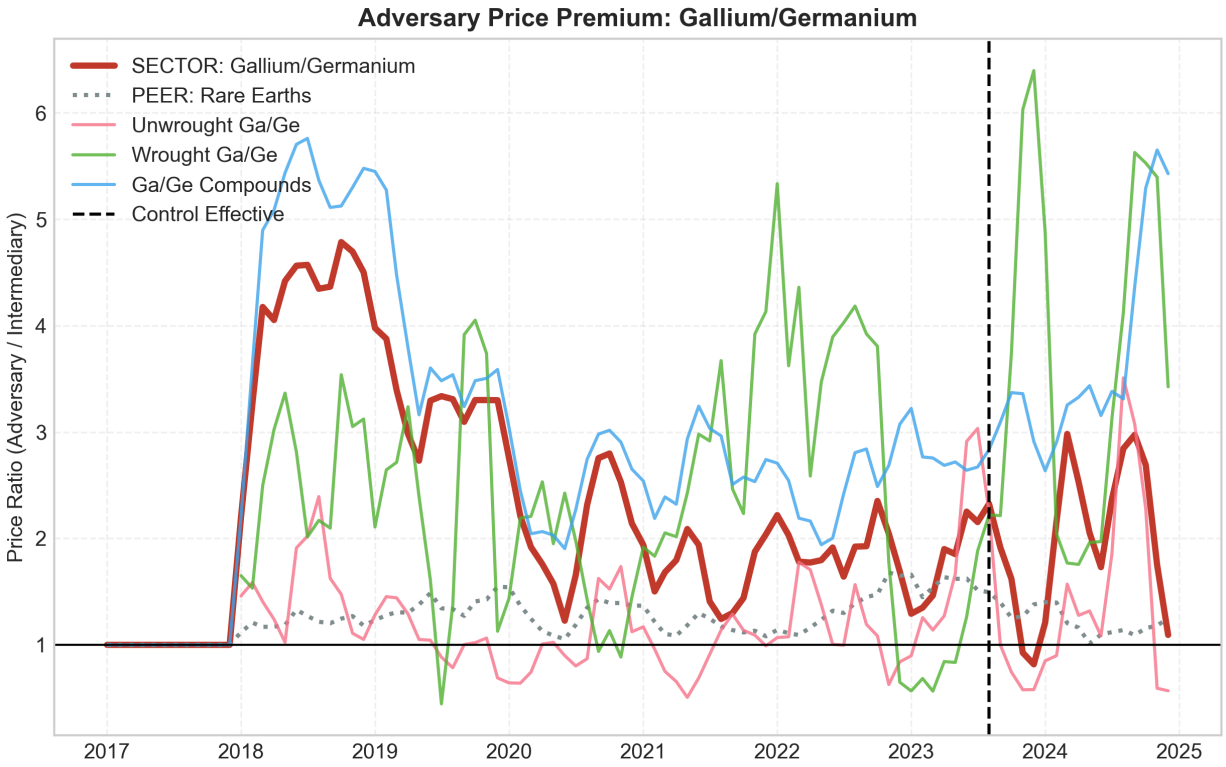

FIG. 3: **Adversary Price Premium for Gallium/Germanium Sector** The price ratio is plotted for the entire gallium/germanium sector (red), the peer comparison group of rare earths (grey dashed), unwrought Ga/Ge (pink), wrought Ga/Ge (green), and Ga/Ge compounds (blue). The ratio is calculated as the weighted average unit price for adversaries over the weighted average unit price for intermediaries and is plotted over the entire study period before and after the August 2023 export control (vertical dashed line). While we see rampant price discrimination in the sector across the entire period, of particular note is the increase in the ratio for Ga/Ge compounds following the control.

shock. For example, mean unit values for wrought Ga/Ge shipments to the United States increase by roughly +$179/kg relative to the average before the control, while major intermediary nodes see sharp declines in unit values for comparable products (e.g., Hong Kong at about −$581/kg and Singapore at about −$406/kg). This pattern of raising prices where you want to impose pain, and discounting where you want the network to keep moving is exactly what we would predict if China is indeed using administrative control coercively, seeking to preserve overall market access while selectively monetizing dependence by adversaries.

When analyzed together, the results presented in Figures 1 through 3 imply that the licensing regime functions less like a binary embargo and more like a state-designed segmentation device. Beijing tries to avoid completely collapsing trade, as this would hurt Chinese suppliers and the Chinese economy in general. Instead, it preserves the ability to clear the market while moving adversaries onto a higher-cost margin. In practice, this means that the control operates as a discretionary rationing mechanism. China enables sellers to charge a wedge that is not competitively arbitraged away by using licenses create artificial scarcity for selected destinations. Indeed, this is the key point. The coercive impact of the policy is not only in reduced availability, but in the creation of a geopolitically indexed shadow tariff that transfers surplus to Chinese firms and, by

extension, to the state that controls the administrative choke.

The use of export controls in this manner also have a coalition management implication from China's perspective. By shifting flows towards selective nodes (and particularly by shifting trade flow towards explicitly controlled nodes like Hong Kong), China is able to create distributional wedges among advanced economies like within Europe, thus raising the political cost of any organized counter-response.

Critically, these patterns are entirely consistent with the predictions made by this paper's dual-track framework. The coercion of Track 1 does not function by maximizing disruption. Rather, it hinges on controlling the terms of the exchange for adversaries through rent, uncertainty, and selective denial. Simultaneously, Track 1 is aided by allowing the Track 2 industrial strategy to stay intact as seen through continued export revenue, sustained processing dominance, and incentives for foreign firms to reorganize around China-aligned nodes. The expected empirical result of the combination of these two tracks is exactly what we see here. Trade does not simple stop. It is filtered via administrative discretion, and exports are rerouted through partners, producing a politically structured market rather than a purely economic one.

B. Graphite

Turning to graphite, the effects of China's export restrictions are felt quite differently, indicating a different underlying mechanism, namely geopolitical filtering. Whereas the drop in the majority of gallium/germanium value was uniformly distributed geographically, in the case of graphite, the emphasis here is on who gets the supply at all, rather than a question of price.

Graphite is central to the production of modern electric vehicle batteries, and China targeted this directly in December 2023 by requiring licenses for exporting high-grade graphite products. The immediate result was a dramatic bifurcation. While exports fell overall, exports to most Western-aligned countries dropped to almost zero, while exports to a handful of non-Western partners surged. China essentially severed the direct supply to its primary competitors in the EV and high-tech space, while relieving its overcapacity by opening trade to intermediaries, resulting in a dramatic restructuring of the supply chain map.

The difference here is significant. As expected in an export ban, in the opening months of 2024, monthly graphite exports from China to Western partners fell by tens of millions of kilograms total per month compared to their pre-control level. In particular, South Korea, the largest importer of Chinese graphite due to its major battery firms, saw a drop of 7.2 million kg per month on average after the policy. Likewise, exports to Japan fell by nearly 2 million kg/month, those to Germany fell by roughly 2.5 million kg/month on average. These contractions are massive. Indeed, they represent a reduction of 30 to 60% of previous volumes for those countries.

This lost volume, however, does not completely disappear. Rather, we see a distinct trend of redirected trade in this period following the export control, with countries outside of the Western coalition and with good relations to China seeing huge increases in volume. Notably, Iran, which had little history of importing significant graphite volume, suddenly saw a roughly $+3.5$ million kg per month jump in Chinese-derived graphite imports on average in six months following the export control. Likewise, the United Arab Emirates, a major logistics hub, saw an increase of almost 3 million kg/month of graphite.

Both of these trends are reflected in Figure 4, which shows the top 5 increases and decreases in graphite export volumes by country after the policy. In this chart, there are two main outliers to the trend described above. India, while coded as an intermediary, sees the third largest trade decrease after South Korea and Germany. Likewise, the Netherlands, while distinctly a Western

ally, sees a very large increase in graphite imports from China. These differences, however, are merely a failure of the coding system, not the theory. While the Netherlands are coded here as an adversary as they are a NATO member and are home to ASML, they are also home to the Port of Rotterdam, which is the largest seaport in Europe. Thus, as a major trading hub, the majority of exports to the Netherlands were bound for other destinations. In India on the other hand, China sought to counter the Make in India initiative that aimed to reduce reliance on Chinese imports. Additionally, the majority of graphite imported to India is not the high quality graphite used in EV batteries, but rather lower quality graphite used as industrial lubricant.

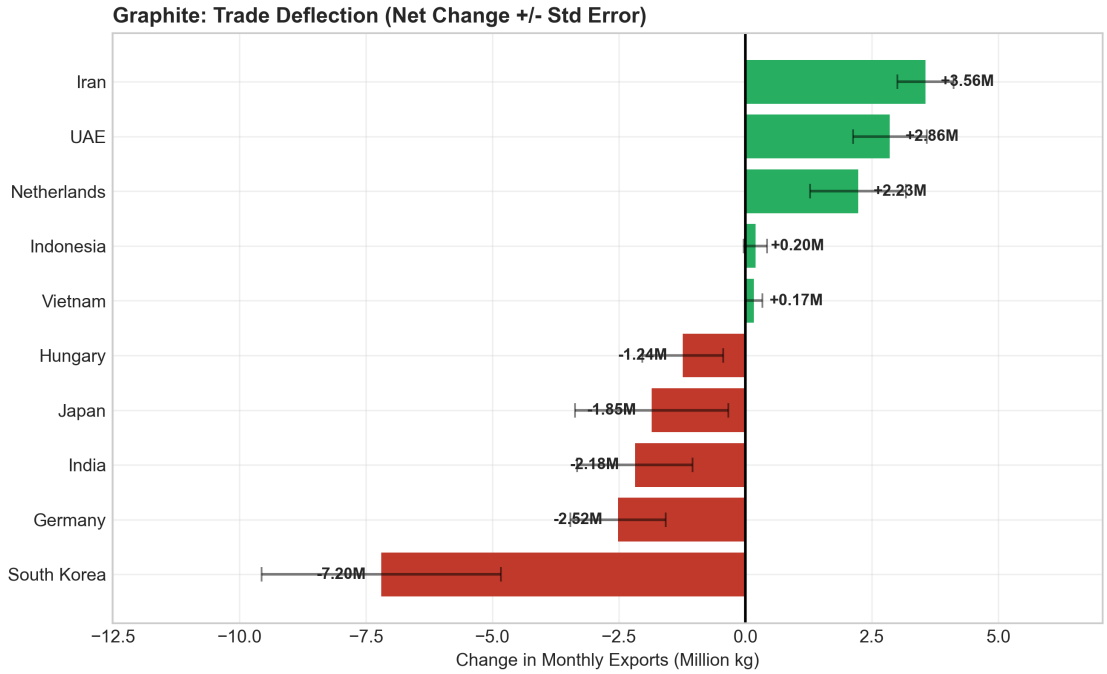

FIG. 4: Trade Deflection in Graphite Exports (Post-Dec 2023). The net change in China's average monthly graphite export volume to major partners is plotted as bars. The 6 month average after the control from Jan–Jun 2024 is compared to the average in the pre-license period from Jun–Nov 2023. Negative values (red bars) indicate countries that imported significantly less graphite from China after the export controls, while positive values (green bars) indicate countries that imported more. Error bars show ± 1 standard error. The data reveals a distinct trend. While South Korea, Japan, Germany and other U.S.-aligned economies saw their graphite supplies from China decrease significantly, Iran and the UAE enjoyed huge increases in imports. Indonesia and Vietnam also gained modest imports. Thus, China can be seen to be filtering its graphite exports away from G7 markets and toward alternative partners, reshaping the supply chain in line with geopolitical considerations.

From the political perspective, the overarching trend is indicative of the fact that Beijing uses its control over the graphite supply chain to favor strategic partners while punishing competitors. When China cuts off access to graphite for G7 countries, it forces either a slowdown in their battery industries or raised costs as they scramble to import from other sources, likely at higher price and lower quality. At the same time, when China floods countries like Iran and Indonesia with graphite, it deepens its ties with those countries and also enables them as future hubs in the battery supply chain potentially for resale or downstream processing. This ultimately undermines Western attempts to diversify away from Chinese materials.

Simultaneously, the other set of countries that see increases in imports of Chinese graphite in the period following the export controls are major trade an logistics hubs like the U.A.E. and the Netherlands. This is in part an indication that trade to the Western adversary countries is not shutting down entirely. China has enough of a production surplus that it must relieve it in part, and entirely losing trade to the Western bloc would be too large of a hit to the economy. As a result, China allows a portion of trade to continue to go out, rerouting through intermediaries to avoid export controls.

Indeed, between the shipping hubs and the strategic partners, the data indicates that at least half of the total volume lost from the adversary bloc is picked up by the intermediary bloc. The remainder of the lost volume is equal to the overall drop in China's graphite exports. This net drop is indicative of the fact that some volume was fully held back or at least not immediately reallocated in full, perhaps in an effort to shake global markets. The key point here, though, is that most of the drop adversaries was compensated for by an increased supply to others.

This targeted diversion is a direct prediction of the theory of dual-track governance presented in this work. Rather than an indiscriminant cut, China uses export licensing as a T-valve, tightening flow to one group of countries while creasing flow to another. This aligns perfectly with the logic of governance-by-chokepoint. As opposed to the gallium/germanium case, instead of extracting rents, China's goal in the graphite sector seems to be to strategically realign the supply chain. When it privileges specific partners by allowing continues access at stable or even discounted prices while denying potentially adversarial countries, Beijing builds a landscape of dependence and goodwill among allies buoyed by Track 2 institutions, while exerting pressure on competitors offering conflicting global orders. As China repeats this pattern with successive periods of export controls and relaxation, this change may translate into a permanent restructuring of global graphite processing and battery production to even more directly consolidate Chinese control at every level of the supply chain.

Also critical to understanding the story of Chinese graphite control is evidence of specification creep, the process of exports shifting to more processed forms of the material in order to relocate the chokepoint further downstream. The logic of this is simple. The further downstream the chokepoint is, the more leverage it enables.

My data on export composition for Chinese graphite is particularly revealing here. Since the implementation of the controls, exports of Chinese raw graphite have fallen significantly relative to refined graphite products. In implementing the controls, China specifically focused on on HS 250410 natural graphite exports while keeping HS 380110 artificial graphite flows more open.

This design essentially limits foreign buyers from refining their own intermediates from raw graphite, forcing them to purchase these intermediates like graphitized or coated anode material directly from China. This can be seen as a meshing of industrial policy with export control. The restriction moves foreign firms up the value chain on China's terms.

This trend can be seen quantitatively in Figure 5, which shows the share of Chinese graphite exports in each bucket. While the decrease in share of Chinese graphite exports that are coded as natural graphite has been relatively monotonic since 2017, in 2022, natural graphite still accounted for roughly 20˜22% of China's graphite export value. After the export controls, however, this dropped sharply to just over 13% and only recovered moderately following the relaxation of the export controls. Importantly, following the export control, China continued to export graphite. It just did so higher up on the value chain. This served to build a dependence of foreign end-users on Chinese refined products rather than just raw materials. China does not want to be the world's graphite mine. They want to control the entire downstream stack.

From a theoretical standpoint, this specification creep is a very subtle manifestation of China's

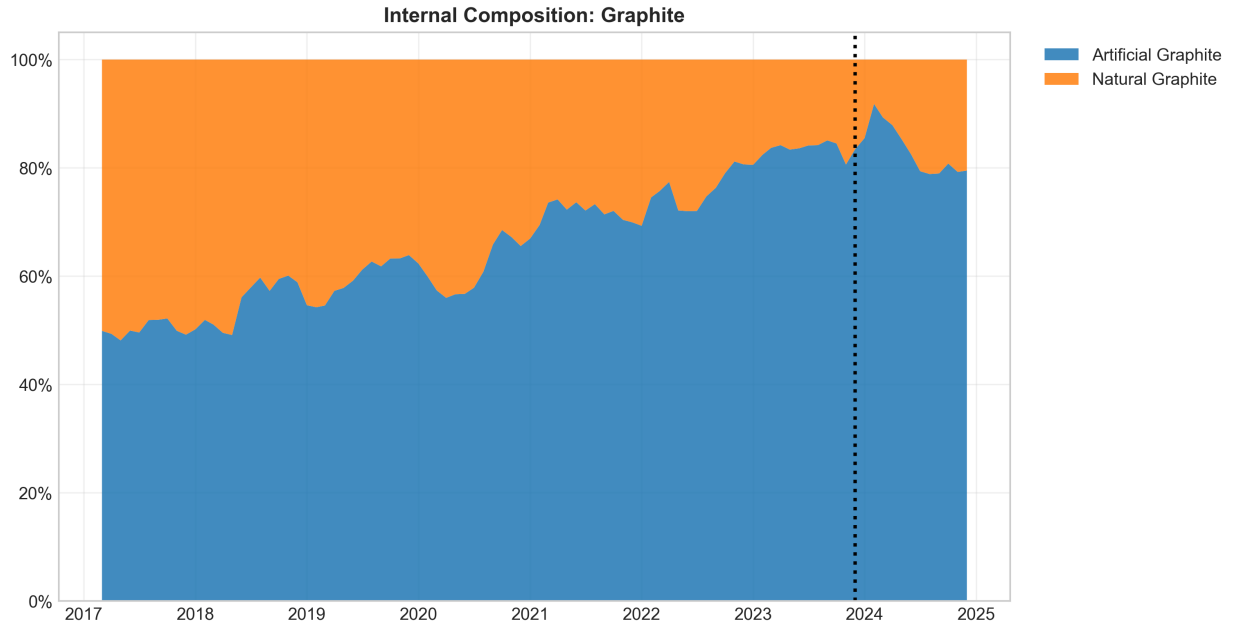

FIG. 5: **Internal Composition of Chinese Graphite.** This plot shows the share of value of Chinese exports of graphite that is artificial graphite (blue) versus natural graphite (orange). Artificial graphite is typically higher value and represents refined intermediates further down the supply chain, while natural graphite exports are either used as industrial lubricant or are refined in the importing country. Historically, natural graphite represented up to 50% of these exports, but over time, the value of natural graphite exports has fallen slowly. Following the December 2023 export control (vertical dashed line) the value of natural graphite exports dropped sharply to just $13-15\%$ of Chinese graphite exports. This specification creep is indicative of Beijing's strategy to push foreign firms to buy further up the value chain.

use of power. In the same way that a weapon is most politically powerful before it is fired, when a chokepoint is blocked completely, it loses much of its geopolitical power. Thus, in order to compensate for and indeed benefit from completely closing one node (in this case raw material exports), China simultaneously creates a new chokepoint one step downstream (in this case by making the world more reliant on its processed graphite). Thus, foreign firms that need graphite for batteries have to either import the finished anode material from China or import it from China-aligned intermediaries that have continued to import raw graphite during the controls and are able to refine it with the help of Track 2 institutions.

We can thus think of specification creep as means of transforming raw material leverage into refined product leverage. This exemplifies governance-by-chokepoint through product classification. By providing a narrow definition of the controlled material while exempting value-added versions, China is able to advance its industrial policy while still imposing costs on adversaries who lose optionality. This export data confirms a distinct compositional pivots that is directly aligned with Beijing's aims of capturing a greater portion of the mineral value chain while locking in foreign dependence at higher and higher steps on the value chain.

VI. SYNTHESIS, CONTRIBUTION AND CONCLUSION

The empirical evidence provided in the preceding section clearly supports the theory of dual-track governance outlined in the Theoretical Approach and gives credence to my claims as to China's Track 1 strategy. Beijing is not simply throttling exports across the board. Rather, it is systematically and surgically reconfiguring trade flows to suit its interests. Depending on the domain, it either seeks to charge adversaries more or to entirely deny them supply, all the while funneling materials to friendly nations and up the value chain. The careful combination of choking and redirecting allows China to maximize its leverage. Adversaries are hurt by the squeeze through a combination of higher costs and supply insecurity, and alternative partners, supported by China's Track 2 institutions, become more dependent on Chinese supply. China plays the game carefully, ensuring that when it tightens controls on exports to Western nations it simultaneously raises the political cost of organized counter-response. Thus China is able to have its cake and eat it too, using export controls to its advantage without losing its influence among adversaries and deepening its influence among intermediaries.

These outcomes support the broader argument made in this paper. China's critical minerals policy should not be viewed as one-off retaliation. Instead, it is a deliberate restructuring of global supply chains into a China-centric network. The granular data down to the kilo and dollar on gallium/germanium and graphite exports shows just how export controls can be used as instruments of statecraft to realign global economic relationships in favor of the controlling state. The rest of this section discusses the implications of these findings for geopolitical theory and international order. The evidence, however, is quite clear. China's dual-track governance built of chokepoints plus institutions is actively reshaping the question of who gets resources, on what terms, and ultimately who holds power in the clean energy and semiconductor supply stack.

A. Synthesis

Across both sectors analyzed here, the central empirical lesson is that chokepoint governance should be understood as market design rather than a crude supply cutoff. For gallium and germanium, the licensing regime is designed to act as a segmentation device, creating a persistent wedge in the terms of exchange. Following the control, adversaries a shifted onto a higher-cost margin, given, in a sense, a geopolitically indexed shadow tariff. Meanwhile, trade continues through selected nodes. The resulting rents are not simply a product of scarcity, rather, they are the consequence of administrative discretion that prevents arbitrage. This allows China to monetize dependence, keeping the broader system intact all the while.

Graphite, on the other hand, is subject to a different but complementary mechanism. China's strategy of geopolitical filtering is specifically designed to maximize influence. Rather than extract rents, China use graphite licensing as a means of reallocating physical supply away from battery and manufacturing centers aligned with the G7 and toward a mixture of strategic partners and logistics hubs. The salient outcome in this setting is not a premium but an enforced remapping of the recipient end of the supply chain. This strategy is tailored to the mineral. Graphite is a bulk and mission-critical input. When countries are unable to import cheap, high-quality Chinese graphite, the downstream adjustment costs are immediate, particularly for firms with tight qualification constraints and limited substitutable supply, like most of the semiconductor and energy stack in the West.

Equally as important as the price and volume results is the compositional result. The decline in lower-value, less-process exports relative to higher-value forms post-control is indicative of the

fact that these episodes are not simply about access. They are about where the choke is placed. When China pinches off a narrower upstream category while keeping downstream, higher-value categories relatively more available, it encourages foreign firms to re-enter the supply chain on China's terms. This forces other nations to purchase refined intermediaries rather than building any independent processing capacity. This policy does not merely exploit existing dependence; instead it actively pushes the binding constraint further down the value chain to a place where switching costs are higher and it is much harder to scale substitute capacity.

B. Theoretical Contribution

The primary contribution of this paper is to debates on weaponized interdependence and international order. I show that chokepoint power can operate through a repertoire that is at once coercive and stabilizing. In classic accounts of hub-and-spoke supply chains, chokepoint control is typically framed as denial. This misses much of the picture. The evidence here points instead to coercion calibrated to preserve the overall functioning of the system itself. China tightens access for some, loosens it for others, maintaining control by using licensing frictions and product definitions to prevent the market from equilibrating away politically meaningful wedges. Rather than an all-or-nothing embargo logic, China is employing a logic of differentiated dependence management.

The dual-track framework is particularly useful here. Track 1 explains the creation of selective scarcity, segmented pricing, and partner switching even in highly globalized commodity systems by means of export controls and granular licensing. Track 2 explains why these changes last. When China repeatedly channels rerouting through a stable set of hubs embedded in wider packages of finance, standards, and offtake relationships, evasion hardens into a lasting reconfiguration of the network. When viewed in combination, the two tracks imply an order-shaping strategy operating below the level of headline diplomacy. China accumulates power over time through a careful politics of classification, licensing, and channel control.

Broadly, these findings are consistent with the idea of a plural, issue-specific order. Rising powers do not need to fully overturn global institutions in order to shape outcomes. Instead, the pursuit of advantage is a question of designing and controlling critical subdomains. As presented here, non-REE critical minerals are exactly such a subdomain, as they are thin, specialized, and institutionally dense. As a result, they offer an unusually clear window into how China combines rules-exploiting tools like licenses, specifications, and technology controls with rules-shaping tools like guidelines, bundled finance, standards to create optionality and leverage while avoiding the implied costs of open confrontation.

C. Policy Implications

One immediate policy implication is that any countermeasure designed to merely replace Chinese supply misses the operational core of China's strategy. Chokepoint governance is implemented through segmentation and rerouting, so the relevant vulnerabilities are not limited to supply concentration. Rather the critical vulnerability is the administrative and institutional channels through which trade is redirected. There are four concrete lessons from this.

1. Stockpiles and alternative sourcing matter, but perhaps more important are policies aimed at reducing exposure to discretionary licensing risk. This means that firms should treat

licensing uncertainty and product-definition risk not as peripheral compliance issues but as core variables in their procurement strategy. Likewise, for governments, this means critical mineral security is in part a problem of governance. Even when physical volumes remain nonzero, licensing regimes can impose large costs.

2. Any coalition policy must treat rerouting hubs as strategic nodes. If China uses intermediaries to absorb displaced volumes and then transship or process, then the transparency and traceability of this process is paramount to resilience. If they do not create credible chain-of-custody and tariff-line visibility, adversary blocs will face de facto dependence even if they have formally diversified.

3. Domestic industrial policy should focus specifically on those segments that exhibit the highest switching costs and that are most vulnerable to the relocation of chokepoints via specification creep.

4. The results of this paper imply that export controls can be used for coalition management and wedge politics. Precisely because China is able to differentially impose costs across allied states or offer selective relief via hub jurisdictions, any attempt at a counter strategy needs to rely not solely on national diversification plans but also incorporate coordinated standards, monitoring, and investment sequencing across allies. Without this, fragmented responses and attempts at reshoring only invite the segmentation that makes the chokepoint strategy effective.

D. Limitations

The conclusions made in this paper come with two important caveats. The first and most significant is that my trade analysis relies on HS6-level trade data, as that is all that is available via the public Comtrade API. Unfortunately, this obscures tariff-line details exactly in the domains where Chinese control operate. While this does not particularly effect the graphite analysis as graphite HS6 designations are very similar to the HS8 level, it is consequential for gallium/germanium, as some HS6 baskets contain both controlled and uncontrolled products. For example, HS811292 contains both controlled unwrought gallium as well as uncontrolled indium. As a result, the true magnitude of licensing effects within the controlled items are attenuated by quantity and unit value patterns of uncontrolled products. Similarly, when I calculate unit values at HS6, I conflate price changes with within-code shifts in grade, purity, and product mix. Where possible, I mitigate this by disaggregating and relying on placebo comparisons, but this analysis cannot fully replace tariff-line or transaction-level data.

The second limitation lies at the heart of trade analysis itself. Trade data alone cannot make any direct observations about contract-level licensing decisions, compliance costs, or any of the smaller-scale mechanisms like inventory drawdowns, requalification timelines, or changes in procurement strategy by which firms adapt. The inference in this paper is thus on revealed outcomes such as prices, volumes, destinations, and composition rather than the full institutional process of licensing and enforcement.

E. Next Steps

If expanded into a larger project, this analysis can go in three directions. First, as elucidated to above, obtaining tariff-line (HS8/HS10) or customs microdata means that one could cleanly separate controlled versus uncontrolled items, more closely identify specification creep, and more credibly estimate the magnitude of the adversay premium in gallium and germanium. Second, by combining export data with the mirroring import data and firm-level disclosures, one could greatly improve the visibility as to rerouting pathways, distinguishing true partner switching from simple reporting artifacts. Lastly, the Track 2 channel needs more direct testing. This could be done by linking the observed rerouting hubs and partner gains directly to measures of Chinese finance, offtake agreements, and standards diffusion. This would allow this work to formally evaluate how the institutional backdrop allows intermediaries to become durable spokes.

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