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RESEARCH ARTICLE

The Power of Withholding: Rare Earth Quotas and Informational Statecraft in China

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Abstract
Why would Beijing abandon three decades of transparent rare earth quota announcements and switch to nondisclosure? This paper argues that withholding information, rather than reducing supply, has become China's preferred way to manage its dominant role in the rare earth industry. We develop a signaling model in which nondisclosure itself creates coercive leverage: by hiding quotas, Beijing forces foreign governments and companies to view uncertainty as a worst-case scenario, leading to precautionary stockpiling, diversification, and industrial policies, even without explicit restrictions. This results in a pooling equilibrium, where both strong and weak types of China use opacity, and outsiders respond as if China is strong. Empirically, the study creates a new dataset of quota announcements from 1990 to 2025, showing how nondisclosure has been linked to price swings, precautionary stockpiling, and policy actions in the U.S., Europe, and Japan. The contribution is threefold: it broadens signaling theory by demonstrating how silence functions as a strategic signal, explores the market effects of opacity, and situates China's rare earth strategy within the broader context of U.S.–China economic and technological competition.

Keywords Rare earths · China · Informational statecraft · Signaling · U.S.–China competition · Opacity

Introduction

In the escalating technological cold war, information remains the ultimate weapon—and in 2025 Beijing took a quiet yet significant step. Regulators assigned quotas for rare earth mining and refining to state-owned enterprises but, breaking with thirty

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years of tradition, chose not to publish the figures [41]. Chinese media characterized the decision as related to the "rising strategic importance" of the sector, sparking speculation that transparency might never return [4]. For global firms, investors, and governments—from U.S. defense contractors to Europe's green-tech manufacturers—this was no ordinary bureaucratic change. It marked a move toward secrecy, weaponizing uncertainty in a critical supply chain [2, 36, 37].

This change did not happen in isolation [9]. It followed China's 2023 revisions to export controls, which placed rare earth separation technology under MOFCOM Announcement No. 23 [30]. The 2024 Rare Earths Regulation intensified this trend, centralizing state control over extraction, processing, and technology flows while reducing transparency [33]. By April 2025, new restrictions on seven heavy rare earths under the Export Control Law—presented as a matter of national security but viewed abroad as retaliation against U.S. tariffs—pushed European prices for dysprosium and terbium to record highs [22].

Rare earths are more than just minerals; they are essential components for electric vehicles, wind turbines, advanced fighter jets, and AI hardware. Since the 1980 s, Beijing's regular quota disclosures have provided fragile signals of production limits and compliance, helping to maintain a degree of trust. Now, nondisclosure forces rivals to prepare for worst-case scenarios, leading to stockpiling, diversification, and expensive industrial subsidies—even without actual production cuts. The economic burden weighs on the United States, Europe, and Japan, while China avoids backlash such as WTO disputes or counter-embargoes.

Quotas are only one dimension. China's opacity also extends to patents—where the bulk of REE-related innovations remain domestically filed, creating a "black box"—and to regulations that restrict technology flows. These layers of informational control magnify coercion, turning uncertainty itself into leverage. The dynamic plays out within the broader U.S.–China technology rivalry, where Washington deploys chip bans, Europe advances its Critical Raw Materials Act, and Beijing reconfigures the game of resource statecraft.

Traditional analyses miss this logic. Economists view rare earths as volatile commodities driven by quota shocks [23]. Political scientists highlight flashpoints like the 2010 Japan embargo [43]. Signaling theory focuses on overt threats and costly signals [14, 32]. However, these perspectives overlook how withholding information can be more effective than material restrictions—being less expensive, more discreet, and legally safer [19].

Earlier work also emphasizes stabilizing interdependence. Chen et al. [7], for example, show that from 2000 to 2022, the U.S. exported concentrates to China while importing refined oxides, creating a mutually beneficial flow that lowered the risk of disruption. This paper argues that such interdependence has come apart. Since 2024, China's move from quota transparency to opacity—bolstered by the Rare Earths Regulation and 2025 export controls—marks a shift from stabilizing interdependence to coercive informational statecraft. While earlier studies highlight material complementarities, the current situation is characterized by asymmetries in information.

We examine quota secrecy within the broader landscape of U.S.–China–Europe technological rivalry. Building on the idea of weaponized interdependence, where network hubs leverage chokepoints [13], and on research about authoritarian information control, where selective disclosure is a strategic tool [17, 25], we highlight rare earths as a small-scale example of geoeconomic brinkmanship [21, 47].

We formalize this mechanism using a signaling model of quota nondisclosure. We demonstrate that opacity shifts a separating equilibrium—in which announcements reveal capacity—into a pooling equilibrium where both strong and weak types withhold information. Foreign actors, unable to discern China's true type, develop pessimistic beliefs and hedge their positions. This results in greater bargaining power for Beijing without the costs associated with embargoes.

The contribution is threefold. Theoretically, the paper expands signaling approaches in international political economy by showing how silence can be a strategic signal. Empirically, it identifies a structural break in quota transparency through a dataset of announcements from 1990 to 2025, linking nondisclosure to price volatility, hedging, and policy responses. Analytically, it situates rare earth opacity within broader U.S.–China rivalry, extending the logic of withholding to patents, standards, and other technological domains [5].

The paper is organized as follows. Section 2 reviews rare earths and China's rise to dominance. Section 3 surveys the literature and highlights the overlooked role of opacity. Section 4 introduces the signaling model. Section 5 provides empirical evidence of the transparency break. Section 6 explores extensions into patents and semiconductors. Section 7 concludes with implications for informational statecraft.

What Are Rare Earth Elements and why Do they Matter

Rare earth elements (REEs) consist of 17 metals, including the lanthanides and sometimes yttrium and scandium, known for their exceptional magnetic, luminescent, and electrochemical properties. These qualities make them vital components in a wide range of advanced technologies. They are found in everything from smartphones and wind turbines to hybrid vehicles, MRI machines, and precision-guided missiles [26]. As Chapman [6] emphasizes, their dual-use nature—serving both consumer markets and military applications—makes them particularly strategic. The same mineral that powers an iPhone also fuels the motors of an F-35 fighter jet, making REEs a crucial link between civilian prosperity and national security [48].

China currently leads in this global industry [1, 20, 29, 33]. It holds about 48% of known reserves, but more importantly, it controls the refining and processing stages of the supply chain. As of 2023, China processed roughly 85% of all REEs and nearly 99% of heavy rare earth separation, which is most vital for defense and high-performance applications. This structural monopoly enables Beijing to influence global flows and prices freely, while countries such as the United States, Japan, and the European Union lack the necessary processing infrastructure and viable alternatives [1]. Dependence on Chinese capacity has thus become a fundamental vulnerability for modern industrial economies.

Table 1 documents China's rare earth mining and refining quotas from 1990 to 2025. It records quota volumes, batch frequency, transparency scoring, and policy context, capturing the evolution of Chinese quota policy across three and a half decades. Four distinct regimes are visible: the *Single Batch Era* of the 1990 s, the

Table 1 Mining and Refining Quota Data (1990–2025)

Year	Quota Batches	Mining Quota (tons)	Refining Quota (tons)	Publicly Disclosed	Policy Context	Source Type	Trans-par-ency Score
1990	1	89,000	89,000	Yes	First public quota	MIIT	8
1995	1	95,000	95,000	Yes	WTO accession prep	MIIT	8
2000	2	73,000	73,000	Yes	Standard operations	MIIT	8
2005	2	65,000	65,000	Yes	Tightening controls	MIIT	8
2010	2	39,990	39,990	Yes	Senkaku dispute cuts	MIIT/Press	7
2011	2	35,000	35,000	Yes	WTO dispute filed	MIIT/WTO	6
2012	2	31,000	31,000	Yes	WTO ruling against China	MIIT/WTO	5
2015	3	105,000	105,000	Yes	Partial liberalization	MIIT	7
2020	3	140,000	140,000	Yes	Regularized system	MIIT	9
2021	3	168,000	168,000	Yes	Post-COVID recovery	MIIT	9
2022	3	210,000	210,000	Yes	Supply expansion	MIIT	9
2023	3	240,000	240,000	Yes	Peak transparency	MIIT	9
2024	?	250,000	250,000	No	Internal quotas only	Internal/Estimated	2
2025	?	260,000	260,000	No	Continued nondisclosure	Internal/Estimated	1

Dual Batch Era from 2000 to 2014, the *Triple Batch Era* from 2015 to 2023, and the *Nondisclosure Era,* beginning in 2024. Across these regimes, quotas fluctuated dramatically, ranging from 89,000 tons in 1990 to a low of 31,000 tons during the 2012 WTO dispute, and then increasing to 240,000 tons by 2023.

Figure 1 illustrates this trajectory across three panels. The first panel displays mining and refining quotas, showing steady growth interrupted by sharp declines from 2010 to 2012, followed by rapid expansion in the 2020s. The second panel displays transparency scores, indicating three decades of steady public disclosure, followed by a sharp decline to nearly zero in 2024–25. The third panel displays batch frequency, emphasizing the institutional standardization of quota announcements into three batches annually by 2020, which was compromised by nondisclosure. The table and figure highlight a clear break in structure: the shift from transparency to opacity in 2024 signifies a major change in China's quota governance.

China's Position in the Supply Chain

Over the past three decades, China has consolidated dominance across nearly every stage of the rare earth supply chain, from mining and refining to alloying and magnet production. This trajectory is rooted in state-led industrial policy, the designation

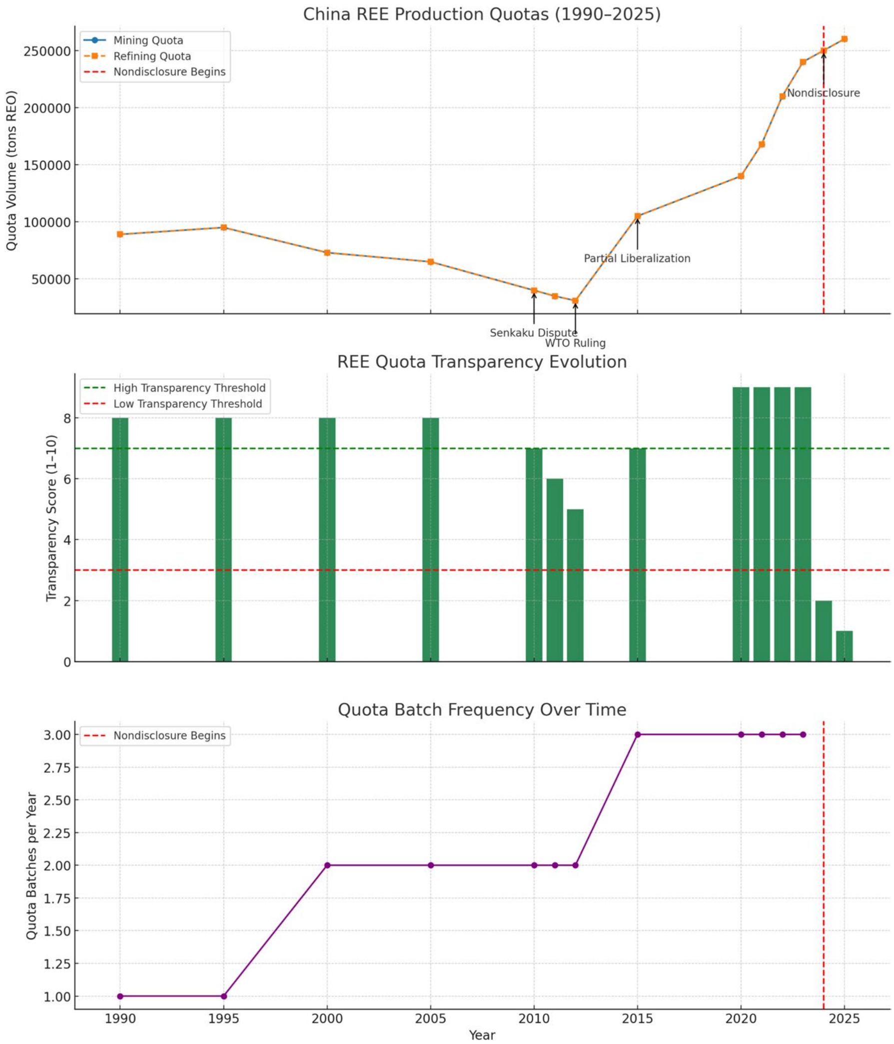

Fig. 1 Quota batch frequency overtime

of REEs as a strategic resource, and successive rounds of consolidation into state-owned champions [1, 50]. By fostering industrial clusters in resource-rich regions such as Inner Mongolia, offering export rebates, and prohibiting foreign investment, Beijing engineered a vertically integrated system in which upstream extraction feeds directly into midstream refining and separation, which in turn anchors downstream magnet and component manufacturing.

Currently, China is not only the largest source of rare earth oxides but also the main supplier of refined inputs and finished magnets for electric vehicles and renewable energy systems [1]. This vertically integrated control allows Beijing to exert influence not only over raw material supply but also over higher-value manufacturing sectors, thereby creating long-term dependency for foreign actors.

European Commission data confirm the extent of this imbalance. The EU relies entirely on China for 100% of its heavy rare earth imports and about 85% of its light rare earth imports [16]. Additionally, recycling makes up less than 1% of demand, leaving Europe with virtually no internal buffer. Heavy REEs—such as dysprosium, terbium, and holmium—are especially important for defense and green technologies, and over 90% of global identified resources are in China. These structural issues mean that EU diversification goals, as outlined in the 2023 Critical Raw Materials Act (targeting 10% extraction, 40% processing, and 15% recycling by 2030), face significant challenges. Unlike more easily substitutable materials, REEs reveal a structural vulnerability: the supply and processing are so concentrated that Western diversification cannot easily bridge the gap.

Econometric evidence underscores this dependency. Fojtíková et al. [15], using panel data from 2000 to 2023, show that EU imports of critical raw materials from China are strongly correlated with EU GDP growth, industrial output share, and China's own export specialization. By contrast, WTO disputes—including the 2012 rare earths case—had no measurable effect on long-run EU import flows. The implication is stark: even legal victories and diversification initiatives cannot undo the structural drivers of dependence. At least one-quarter of the EU's CRM demand will continue to be met by imports from China through 2030, regardless of policy efforts.

These findings align with recent episodes of regulatory escalation. The October 2024 Rare Earth Regulation codified Chinese control across mining, refining, and distribution, creating a domestic traceability system while offering no transparency to foreign markets. In April 2025, Beijing tightened its grip by imposing export restrictions on seven heavy rare earths—including dysprosium and terbium—under the Export Control Law, ostensibly on national security grounds but in practice as retaliation against U.S. tariffs. European spot prices for dysprosium and terbium nearly tripled in the weeks following the announcement [22]. These events illustrate how China's strategy has moved beyond quotas into a layered regime of regulation, selective export controls, and patent opacity, each reinforcing the others to magnify uncertainty.

This combination of material dominance, structural EU vulnerability, and institutionalized opacity defines the strategic environment. It also highlights why conventional static models are insufficient. What matters is not simply China's current market share but the uncertainty surrounding its future actions—uncertainty that foreign actors must internalize in their diversification, hedging, and investment strategies. Modeling this interaction requires a framework, such as a Partially Observable Markov Decision Process (POMDP), that can capture how beliefs evolve under opacity and how these beliefs shape long-term strategic behavior.

Regulatory Escalation: From Quotas to Opacity

China's reliance on rare earths as a tool of statecraft first became evident during the 2010 embargo on shipments to Japan, amid the Senkaku Islands dispute. The sudden cutoff caused global price spikes, forced Japan into costly stockpiling and diversification, and showed that REEs could be used as a form of geopolitical leverage rather than just traded commodities [50].

In response, the United States, European Union, and Japan challenged China at the WTO, and in 2014 the Appellate Body ruled that Chinese export quotas and duties on rare earths broke its accession commitments. While the ruling forced Beijing to stop overt quantitative restrictions, it also marked a turning point. China moved away from legally vulnerable tools toward more subtle, harder-to-challenge methods of control.

The initial stage of this transition was informational. Since 2021, China has stopped publishing its annual production and export quotas, abandoning the practice of openly sharing data. This intentional nondisclosure created a lasting state of uncertainty: foreign governments and companies, lacking reliable information on Chinese output, had to hedge against worst-case scenarios, increasing their costs even without official supply reductions. What once was a critical bottleneck became an informational one, where opacity itself served as leverage.

The second phase involved legal and regulatory codification. The October 2024 Rare Earth Regulation consolidated state control across the entire value chain—mining, refining, smelting, distribution, and export—under a single framework. It introduced a quantitative control system, a mandatory traceability regime, and severe penalties for violations. While presented as an effort at industrial rationalization, the regulation effectively institutionalized opacity: China gained complete internal visibility over firms through traceability while withholding transparency from foreign markets.

The third phase has been outright securitization through export controls. In April 2025, Beijing invoked its 2020 Export Control Law to restrict exports of seven heavy rare earths, including dysprosium and terbium—elements indispensable for EV drivetrains, wind turbines, and defense platforms. Although framed as national security safeguards, the measures were widely interpreted as retaliation against U.S. tariffs. Their impact was immediate: European spot prices for dysprosium and terbium nearly tripled, underscoring how even partial restrictions and customs delays can destabilize global supply chains [22, 44].

The progression also reveals why rare earths should be viewed not just as a battle over quantities, but as a struggle over information, where uncertainty is employed as a weapon. It also paves the way for the modeling approach of this paper, which treats quota nondisclosure and patent opacity as internal state variables in a Partially Observable Markov Decision Process.

Unlike traditional theories of "resource power," which focus on scarcity, this view emphasizes the coercive strength of network position and chokepoint control. The rare earths case thus shows how opacity and interdependence reinforce each other: nondisclosure and patent opacity raise uncertainty, while network centrality makes that uncertainty a source of bargaining power.

The next section situates this argument within existing scholarship, showing how resource politics, strategic trade, and international relations literatures address rare earths—and why they fall short in capturing the power of opacity.

Literature Review

Much of the research on rare earths views them primarily as a resource that can be used for coercion. Analysts highlight China's control over mining and refining, arguing that Beijing can manipulate exports to pressure rivals [18, 27, 50]. The 2010 halt of shipments to Japan during the Senkaku/Diaoyu dispute is often seen as a textbook example of an embargo, a clear denial of supply used as a geopolitical weapon.

As Mancheri et al. [28] point out, the incident revealed vulnerabilities in resource-dependent countries and sparked new debates on supply chain resilience. The comparison to past oil shocks was quick: just as OPEC was once believed to hold Western economies hostage, China is frequently seen as using rare earths in a similar way (Wilson [45]). However, these perspectives share a common assumption—that power comes from limiting physical quantities—while ignoring the idea that uncertainty alone can cause similar adjustment costs.

Recent work on *weaponized interdependence* underscores this point. Farrell and Newman [13] argue that states occupying central positions in global economic networks can exploit chokepoints to exercise coercive leverage. Their framework shows that interdependence itself becomes a source of power, not only through sanctions or price manipulation but through the ability to shape and sometimes withhold signals. While their cases focus on financial messaging and technology standards, the logic extends directly to resource governance: China's management of quotas illustrates how network centrality, combined with opacity, can force rivals into costly hedging without overt restrictions.

Economists examine the issue through the lenses of comparative advantage and strategic trade. Studies highlight China's artificially low prices aimed at pushing competitors out [23], government subsidies for domestic firms, and vertical integration spanning mining, refining, and magnets. These patterns reflect the Brander–Spencer model of strategic trade policy, where governments intervene to capture international market share [3]. They also relate to broader debates over infant industry protection, intellectual property, and state-led industrialization.

However, this literature assumes transparent information environments: prices are considered trustworthy signals of scarcity, and quotas are viewed as fixed external parameters. When disclosure stops, these assumptions break down. Markets cease to function as information systems, and opacity itself turns into a strategic tool.

International relations scholarship on coercion provides a valuable additional perspective. Classic works such as Schelling's *Arms and Influence* (1966) stress the importance of credible communication in bargaining. Later refinements distinguish between tying hands and sunk-cost signals [14, 32], while more recent work emphasizes bargaining under incomplete information [40].

Yet, these insights have been mostly applied to military crises, nuclear deterrence, or sanctions [39]. Economic statecraft is still primarily modeled through observable instruments—such as tariffs, embargoes, and financial restrictions—rather than informational strategies. The idea that leverage can derive from withholding information, not just imposing material costs, has received little sustained attention in IR theory.

A small but expanding body of research recognizes opacity as a strategic asset. Colgan [11] demonstrates how uncertainty regarding Saudi spare capacity enhances OPEC's influence. Cheung and Qian [8] find that China's limited transparency about its foreign reserves increases their policy impact. In the technology sector, Maskus and Merrill [31] emphasize how secrecy surrounding dual-use patents can delay rival innovation. These studies share a key insight: opacity is not a flaw but a tool of statecraft. However, this insight remains scattered across different fields, and there is no unified framework to explain how informational opacity can turn routine practices—such as quota disclosure—into leverage instruments.

The literature on rare earths highlights this gap. Quotas are typically viewed as tools for controlling environmental harm or stabilizing prices, and IR scholarship mainly cites them as evidence of China's intent to restrict supply. The belief that quotas are always disclosed, with only their size varying, remained unchallenged for thirty years. The shift after 2024 toward nondisclosure reveals that the visibility of quotas is itself a strategic factor with significant consequences.

Authoritarian information-control research provides a crucial connection. Studies highlight that authoritarian regimes often practice selective transparency: releasing some data to boost credibility while withholding other information to maintain flexibility [17, 25]. Applied to rare earths, this logic indicates that nondisclosure is not unusual but aligns with broader authoritarian strategies of selective signaling. By withholding quota figures, Beijing increases discretion, diminishes external accountability, and heightens foreign uncertainty—thus strengthening bargaining power.

Thus, the literature leaves a significant gap. Resource politics links power to material control, strategic trade assumes transparent markets, IR coercion theory focuses on observable threats, and authoritarian transparency studies have not been systematically applied to resource governance. No One considers the possibility that the signal itself might be withheld, leading to costly effects through uncertainty. Nondisclosure of quotas is only one dimension of informational statecraft. A parallel and increasingly important domain is intellectual property, where opacity is cultivated through patents and export controls.

Patent Opacity: Weaponizing Intellectual Property

If quota nondisclosure and regulatory controls are China's first two stages of opacity, the next frontier is in the realm of intellectual property. While trade law can challenge control over physical flows, managing knowledge through patents, licensing, and technology export rules exists in a much opaquer space. Patents enable Beijing to influence expectations by limiting access to rare earth technologies and by concealing the path of its own innovation. In this way, patent opacity isn't just a passive side effect of state policy but an active strategic instrument.

One dimension of this strategy is the overwhelming concentration of Chinese patent filings in the domestic system. Recent surveys indicate that more than 90% of REE-related patents filed by Chinese inventors never enter international patent systems, such as the Patent Cooperation Treaty (PCT) or the USPTO). By confining the bulk of its filings to the Chinese Patent Office, Beijing creates a "black box" in which foreign competitors cannot reliably track the direction of innovation. What appears in global patent databases is only a fragment of the actual research pipeline, forcing foreign actors to assume that unobserved technological progress may be occurring behind the wall. This informational asymmetry mirrors the nondisclosure of quotas: the opacity itself creates leverage by inducing worst-case expectations.

A second tactic involves intentionally using noise to hide signals. China's domestic patent landscape is saturated with utility model patents, many of which are incremental or low-quality filings. This large volume makes it very difficult for foreign analysts to tell genuine breakthroughs from redundancies supported by government funding. By flooding the information environment, Beijing raises the cost of technological intelligence and slows down rivals' ability to develop diversification strategies. This approach is like quota nondisclosure in its basic logic: uncertainty becomes the weapon, not the actual data.

A third dimension is direct technology export restriction. In December 2023, China banned the export of REE extraction, separation, and alloy production technologies, formalizing its grip on knowledge flows. This was followed by the 2024 Rare Earth Regulation, which codified technology controls alongside physical quotas. These restrictions, like the 2025 export controls on heavy REEs [22], reinforce the securitization of intellectual property, transforming proprietary knowledge into a state-controlled instrument of coercion. Foreign firms seeking to develop non-Chinese refining or magnet capacity must either pay prohibitive licensing fees, develop technologies independently at great cost, or risk running afoul of Chinese enforcement.

Patent opacity thus complements quota opacity and regulatory opacity, forming a layered system of informational statecraft. Where the first phase targeted physical flows, the second institutionalized opacity through law, and the third weaponized export controls, the fourth now extends uncertainty into the realm of technological progress itself. Each layer amplifies the others: patent thickets increase the difficulty of interpreting regulatory intent, while technology export bans multiply the risks of quota nondisclosure. The cumulative effect is to trap foreign actors in a cycle of hedging and delay, raising the costs of diversification and reinforcing dependency.

This is exactly why the rare earth conflict must be viewed as a belief-driven process. Static trade or bargaining models fail to capture how opacity builds up across different areas. A POMDP framework, on the other hand, formalizes the complex interaction between hidden technological states, observable but noisy signals, and shifting foreign beliefs. In this way, patent opacity is not just an empirical puzzle but a key theoretical element: it shows how control of information—in patents as well as in quotas—has become the crucial resource in geoeconomic competition.

Theoretical Framework: A Signaling Model of Quota Nondisclosure

The rare earth quota system provides a clear test for a signaling model. For over thirty years, China communicated stable, institutionalized, and publicly observable signals through annual or semiannual quota announcements. The abrupt halt in disclosure in 2024 serves as a quasi–natural experiment, enabling us to assess how withholding information affects beliefs and actions in global markets.

Classic signaling theory emphasizes credibility through costly signals; our contribution is to formalize the effect of a withheld signal [10]. The cost imbalance favors one side: disclosure risks reputational and legal issues for Beijing, while non-disclosure introduces uncertainty costs for foreign actors. When misjudging Chinese capacity could be disastrous, the absence of information itself becomes a strategic tool that shifts adjustment costs outward.

We ground the model in two context-specific assumptions. (i) Cost asymmetry: the penalty for pressing and being wrong, δ, is large relative to the finite cost of hedging, A (stockpiling/diversification are expensive but manageable; a supply failure can stall defense and clean-energy sectors). (ii) Equilibrium selection: post-2010 experience induces pessimistic priors about Chinese resolve; when downside risks loom large, prudent actors adopt the equilibrium in which they hedge under uncertainty.

Timing of the Game

1. Nature draws China's capacity type $Q \in \{Q_H, Q_L\}$ with prior $\Pr(Q=Q_H)=\mu_0$.
2. China observes Q and chooses whether to disclose (D) or not disclose (ND).
3. Foreign actors observe only the signal $S \in \{D, ND\}$. If $S=D$, they learn China's true type. If $S=ND$, they form beliefs $\mu=\Pr(Q=Q_H \mid ND)$.
4. Foreign actors choose an action: • Hedge (H): stockpiling, diversification, or concessions. • Press (P): sanctions, litigation, or accelerated domestic production.
5. Payoffs realize: China receives π_C (leverage net of costs); foreign actors receive π_F conditional on action and type.

Figure 2 depicts the extensive form: left branch—disclosure/separating; right branch—nondisclosure/pooling with a dashed information set. The belief cutoff μ^* is shown at the ND decision node.

Game Structure

Nature selects Q. China privately observes Q and sends $S \in \{D, ND\}$. Foreign actors observe S and choose $a \in \{H, P\}$.

Chin's Payoffs $\pi_C = L(Q) - C(Q) - \phi_D 1\{S = D\} - \kappa 1\{a = P\}$

With $L(Q_H) > L(Q_L)$ $\phi_D > 0$ captures reputational/WTO exposure from disclosure; $\kappa > 0$ is the penalty if foreigners press.

Foreign Actors $$\pi_F(H) = -A$$

$$\pi_F(P \mid Q_H) = -\delta$$

$$\pi_F(P \mid Q_L) = +\gamma$$

where $A>0$ is the cost of hedging, $\delta>0$ the loss from pressing a strong China, and $\gamma>0$ the gain from pressing a weak one.

Beliefs and Strategies

Upon observing ND, foreigners form the posterior $\mu=\Pr(Q=Q_H \mid ND)$. The expected payoff from pressing is

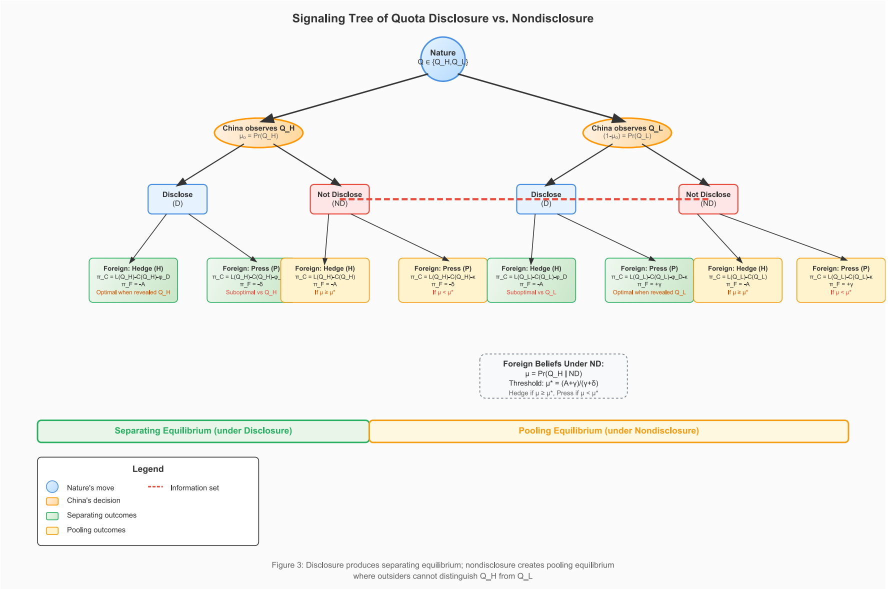

Figure 3: Disclosure produces separating equilibrium; nondisclosure creates pooling equilibrium where outsiders cannot distinguish Q_H from Q_L

Fig. 2 Signaling game tree

$$\mathbb{E}\left[\pi_F(P) \mid ND\right] = (1-\mu)\,\gamma - \mu\delta$$

Hedging is preferred iff

$$\mathbb{E}\left[\pi_F(P) \mid ND\right] < -A \iff \mu \geq \mu^* = \frac{A+\gamma}{\gamma+\delta}$$

Thus, whenever beliefs about Chinese strength exceed μ^*, hedging dominates—even if the true type is Q_L.

Equilibrium Logic

- **Separating under disclosure** (D): types are revealed; foreigners match: hedge if Q_H, press if Q_L.
- **Pooling under nondisclosure** (ND): both types can rationally choose opacity; foreigners cannot separate and therefore hedge whenever $\mu \geq \mu^*$. The withheld signal—rather than a quantity cut—shifts costs onto outsiders and creates bargaining leverage.

Comparative Statics (Table 2; Proofs in Appendix 1)

From $\mu^* = \frac{A+\gamma}{\gamma+\delta}$:

- Hedging cost $A \uparrow \Rightarrow \frac{\partial \mu^*}{\partial A} = \frac{1}{\gamma+\delta} > 0$: higher threshold to hedge (at a fixed μ); opacity remains potent where beliefs are high.

Table 2 Comparative Statics

Parameter Change	Effect on Cutoff μ*	Strategic Interpretation
Hedging cost A↑	$\frac{\partial \mu^*}{\partial A} = \frac{1}{\gamma+\delta} > 0$	Raises the cutoff: foreigners need stronger beliefs in Chinese strength before hedging. Opacity becomes more coercive where beliefs are already high.
Penalty of pressing strong China δ↑	$\frac{\partial \mu^*}{\partial \delta} = -\frac{A+\gamma}{(\gamma+\delta)^2} < 0$	Lowers the cutoff: expands the range of beliefs where hedging is optimal. Opacity's leverage increases as the cost of misjudging China rises.
Gain from pressing weak China γ↑	$\frac{\partial \mu^*}{\partial \gamma} = \frac{\delta-A}{(\gamma+\delta)^2}$ (conditional)	Ambiguous: if $\delta > A$, the cutoff rises and pressing is more attractive; if $A > \delta$, the cutoff falls and hedging remains robust.

All derivatives are evaluated at the equilibrium threshold $\mu^* = \frac{A+\gamma}{\gamma+\delta}$. The sign of $\frac{\partial \mu^*}{\partial \gamma}$ depends on whether the penalty for pressing China (δ) exceeds the hedging cost (A)

- Penalty vs. strong China $\delta \uparrow \Rightarrow \frac{\partial \mu^*}{\partial \delta} = \frac{-(A+\gamma)}{(\gamma+\delta)^2} < 0$: larger belief region in which hedging is optimal; opacity's leverage expands.
- Gain from pressing weak China $\gamma \uparrow \Rightarrow \frac{\partial \mu^*}{\partial \gamma} = \frac{(\delta-A)}{(\gamma+\delta)^2}$ (sign conditional): when $\delta > A$, pressing becomes relatively more attractive; when $A > \delta$, hedging remains robust.

Nondisclosure enlarges the set of states of the world in which outsiders act as if China is strong. The model thus explains how informational opacity, by raising μ and shaping μ^*, generates leverage without reducing physical supply.

Figure 2 provides the labeled game tree (separating under D; pooling under ND; dashed information set; belief annotation $\mu = \Pr(Q_H | ND)$; threshold μ^*). Table 2 reports the comparative statics in a journal-safe format.

The math with full derivations in Appendix 2 shows how uncertainty itself can give China leverage. The formal model treats two types of China— "strong" or "weak"— and two choices: disclose quotas (D) or withhold them (ND). Foreign actors also face two choices: hedge (H) by stockpiling or diversifying, or press (P) by challenging China Table 3.

The proofs show that when opacity is high, both strong and weak types of China find it best to withhold information. This results in a pooling equilibrium: foreign actors, unable to tell the difference between types, act as if China is strong and hedge their bets. The model defines the specific conditions when acting becomes too risky, indicating that nondisclosure alone leads to costly foreign adjustments without Beijing facing the actual legal or material costs of embargoes.

This clarifies the 2024 pause in quota transparency and shows how silence can serve as a credible signal. By broadening the range of situations where outsiders see China as assertive, nondisclosure provides bargaining leverage. The framework also goes beyond quotas, offering a theoretical basis for understanding opacity in patents, intellectual property, and other areas of geoeconomic rivalry.

The next step is to examine whether the break in disclosure patterns after 2024 corresponds with empirical signatures consistent with this mechanism—price volatility, precautionary hedging, and policy shifts that reflect the logic of opacity rather than material restriction.

Empirics

The purpose of the empirical analysis is not to "test" the signaling model in a narrow econometric sense but to demonstrate how its logic maps onto observable dynamics in the rare earth market. The model establishes that nondisclosure enlarges the set of states in which outsiders must act as if China is strong, forcing them to engage in precautionary hedging regardless of the proper type.

To evaluate this mechanism, the empirical section examines how the structural break in quota transparency after 2024 coincided with measurable responses, including volatility in rare earth prices, *precautionary stoc*kpiling, and new rounds of industrial policy in the United States, Europe, and Japan. Data are derived from official MIIT/MNR quota notices (see Appendix 1 for full document references).

By situating quota nondisclosure within a three-decade dataset of announcements and contextualizing it with secondary reporting, the analysis shows how informational opacity operates in practice. In short, the empirics anchor the model historically and illustrate its predictive scope, linking the formal logic of μ and μ^* the real-world costs imposed on China's rivals.

The empirics also supports the paper's predictive claim: if opacity can substitute for material restriction in quota policy, similar logic should apply in other informational domains. In Section 5, I extend this reasoning to patents, where nondisclosure or classification may function as a new form of strategic denial. The empirical story of quotas thus anchors the model historically while pointing forward to its future applications.

Separating Vs. Pooling: The Structural Break in Quota Disclosure

The quota dataset (2000–2023) shows a separating equilibrium: quotas were regularly announced, allowing outsiders to distinguish between restrictive and permissive types. From 2024 onward, nondisclosure years create a pooling equilibrium: outsiders cannot infer China's type, only that opacity itself has become a deliberate strategy. This structural change is evident in the dataset—disclosure years are coded with mining and refining tonnages, while nondisclosure years are coded as missing signals—and marks the point where the signaling environment significantly shifts.

In the model, opacity induces belief updating toward worst-case scenarios. The empirical record confirms this. Price series for dysprosium and neodymium spiked after missed announcements rather than after quota cuts. Firms in Japan and Europe stockpiled preemptively; U.S. agencies invoked uncertainty to justify subsidies and contracts. The volatility functioned as if China had restricted output—consistent with the model's prediction that when signals are withheld, followers rationally hedge against the most costly interpretation.

The Follower's Dilemma: Regional Vulnerability and Policy Response

Figure 3 is a heatmap that shows data in a color-coded grid, making patterns of concentration, intensity, or risk immediately visible. This vulnerability heatmap illustrates cross-national exposure to Chinese rare earth opacity by considering three factors: (1) dependence on Chinese processing for imports, (2) sectoral concentration in high-REE industries, and (3) past crisis exposure. Darker areas on the map represent higher overall vulnerability.

The results show that the United States, European Union, Japan, and South Korea cluster in the upper-right quadrant, indicating both high dependency and high potential cost. This is not a neutral distribution; it reflects the structural position of these economies in the rare earth game. From the perspective of the signaling model, the heatmap shows where the follower's dilemma is most intense. States in the darker zones cannot easily replace Chinese supply, so when Beijing withholds quota information, they are forced to treat the signal as potentially restrictive—even if no material cuts are announced. The heatmap thus visualizes the game's payoff asymmetry: opacity is disproportionately costly for highly dependent followers.

While the heatmap in Fig. 3 illustrates the relative vulnerability of follower states in the rare earths game, Fig. 4 goes a step further by quantifying the projected regional impact of nondisclosure. The measure combines three dimensions of adjust-

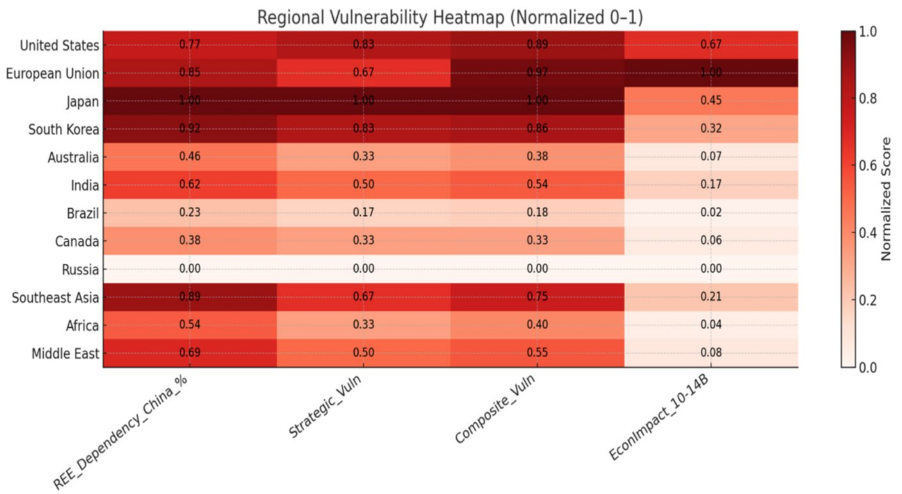

Fig. 3 Vulnerability heatmap

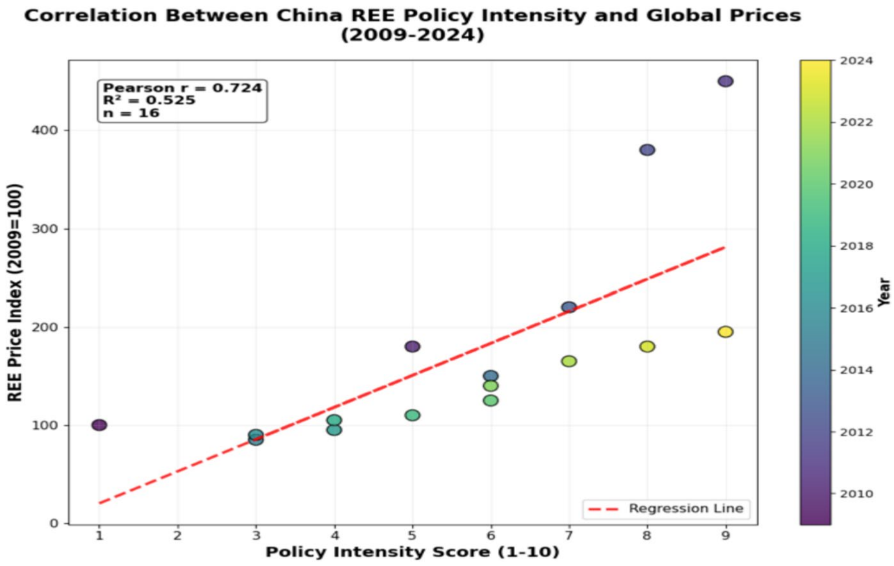

Fig. 4 Regional impact measures

ment costs: (1) stockpiling expenses due to quota opacity, (2) industrial policy spending aimed at diversification and substitution, and (3) exposure to price shocks in critical sectors. Each is normalized by GDP to enable comparisons across economies of different sizes.

The results show that the European Union and Japan bear the largest proportional burdens, with adjustment costs that exceed those of the United States and South Korea. This reflects both their higher baseline dependence on Chinese supply and their limited capacity for rapid substitution. The U.S. and South Korea, while less exposed proportionally, still register significant projected costs as they pursue supply-chain hedging, especially in defense and advanced manufacturing.

The purpose of this figure is to demonstrate that nondisclosure functions not only as a signal in relative strategic terms but also as a material generator of quantifiable adjustment costs. In game-theoretic terms, it illustrates the payoff asymmetry across followers: states facing higher exposure have more substantial incentives to escalate defensive responses, confirming the model's prediction that opacity itself shifts the distribution of expected payoffs.

Figure 5 explores how states turn vulnerability into policy actions by comparing dependence on Chinese rare earths with the level of diversification and industrial policies selected after quota opacity. Unlike the heatmap (Fig. 3), which shows relative exposure, and the impact bars (Fig. 4), which display total adjustment costs, the scatterplot illustrates the behavioral response of followers in the signaling game.

The x-axis measures structural dependence, such as the share of rare earth imports from China and the exposure of high-tech sectors, while the y-axis shows observable policy responses like stockpiling commitments, subsidies for domestic or allied processing, and investments in recycling or substitution. Each data point represents a state (U.S., EU, Japan, South Korea, and others), with the slope indicating the

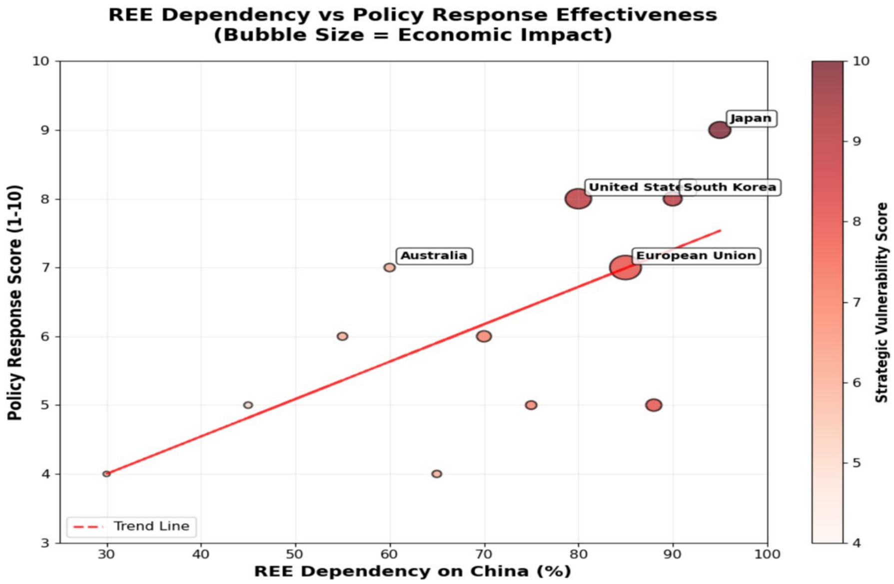

Fig. 5 Dependency–response scatterplot

strength of the dependency–response relationship (See Appendix 3 for representative stockpiling and policy documents).

The results demonstrate a clear pattern: states with both high dependence and prior crisis exposure (notably the EU and U.S.) adopted the strongest defensive measures, including accelerated industrial policy and large-scale diversification programs. Japan and South Korea, while also dependent, exhibited slightly less aggressive responses, reflecting their dual strategies of stockpiling and diplomatic engagement with Beijing. This distribution confirms the model's prediction that greater variance in expected payoffs pushes followers toward costly escalation, even when material restrictions are absent.

From a game-theoretic perspective, the scatterplot illustrates the follower's dilemma: highly exposed states cannot afford to assume benign intentions under opacity, so they hedge by investing in costly but protective measures. Less dependent states, by contrast, can afford to "wait and see." This asymmetry in responses reflects the payoff heterogeneity central to the signaling model.

Figure 6 disaggregates the impact of quota opacity by sector, showing which industries bore the heaviest adjustment costs.

The figure ranks technology-intensive and green energy sectors against more traditional industrial applications, measuring exposure through three metrics: price volatility of key inputs (e.g., neodymium for wind turbines, dysprosium for EV motors), stockpiling expenditures, and substitution difficulty. The bars reveal that technology and green energy sectors consistently sit at the top of the impact scale, with higher adjustment costs than defense or general manufacturing.

In summary, Figs. 3, 4, 5, and 6 provide a layered empirical demonstration of the signaling game. Figure 3 establishes the baseline by mapping cross-national vulnera-

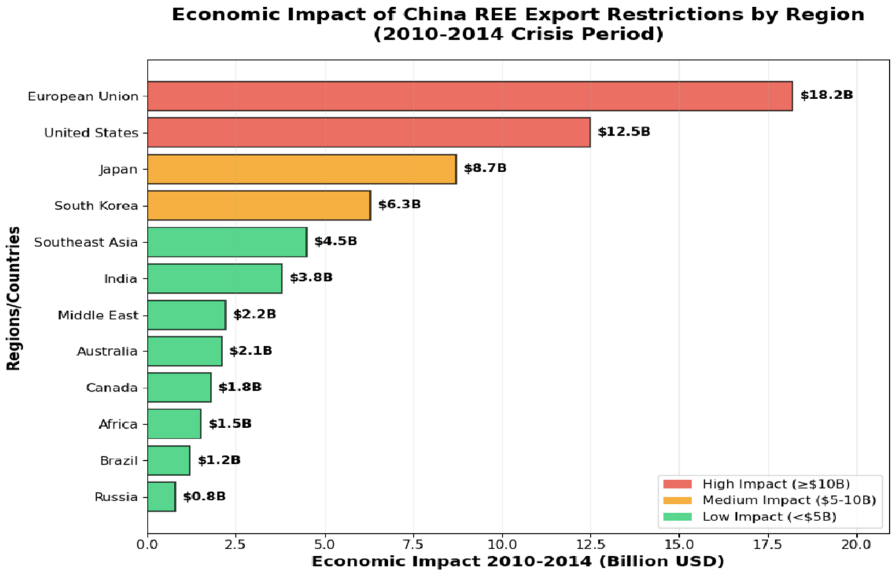

Fig. 6 Economic impact of REE by region

bility, highlighting which states fall into the high-cost quadrant of the game. Figure 4 then translates these vulnerabilities into projected adjustment costs—stockpiling, policy expenditures, and exposure to price shocks—normalized by GDP.

Figure 5 adds the behavioral perspective, showing that highly dependent states with prior exposure to crises escalated defensive measures more aggressively, consistent with the model's prediction that payoff variance drives precautionary investment. Finally, Fig. 6 disaggregates impacts by sector, demonstrating that opacity is most consequential in technology and green energy domains where substitution is most difficult. Together, this sequence mirrors the signaling logic: opacity alters perceived payoffs, produces precautionary responses, and amplifies leverage where dependence and substitution constraints are most significant.

The empirical implication is clear: the distribution of adjustment burdens matches the pooling equilibrium predicted by the model. Since nondisclosure prevents followers from distinguishing between a benign quota (Q^L) and a restrictive one (Q^H), they respond as if a worst-case scenario is likely. Regional impact scores increase accordingly, even without confirmed supply disruptions. Therefore, Fig. 2 shows that opacity functions as a strategic tool, shifting costs onto rival economies without China facing immediate material sacrifices (see Appendix 4 for robustness checks).

Predictive Scenarios and Diplomatic Risks

The signaling model discussed above is not only useful for explaining past actions but also offers valuable insights into China's future rare earth (REE) policy path and its geopolitical implications. By interpreting China's choices as signals of either leverage or concession and analyzing how competitors update their beliefs in response to these signals under uncertainty, the framework helps identify when tensions are expected to peak, when they might calm down, and which strategies are best for lowering risk. In this way, the model functions both as an explanation and as a predictive tool for diplomatic risks over the next decade.

Figure 7 (top panel) presents four stylized diplomatic scenarios extending through 2035: a baseline, an escalation pathway, a crisis trajectory, and a de-escalation path. The baseline scenario depicts a gradual easing of tensions, reflecting the possibility that China uses its REE leverage sparingly and rivals respond with modest but steady diversification. The escalation and crisis scenarios, by contrast, show converging trajectories that culminate in a risk peak around 2030–2032.

In these cases, informational opacity and signaling interact with increased geopolitical competition, leading to ongoing volatility and policy conflicts. Lastly, the de-escalation path shows the less likely but still possible outcome of cooperative management, where persistent diplomacy reduces mutual suspicion and lessens the importance of REEs as a coercive tool. These scenarios model the signaling game dynamically: different combinations of signals and responses create varied diplomatic equilibria.

The period of greatest vulnerability is clear in escalation and crisis situations. Between 2030 and 2032, China's coercive threats appear most credible because opponents have not yet developed strong counter-signals. In game theory, this is the window where the probability threshold most favors Beijing: foreign actors cannot accurately gauge China's capacity, but the costs of underestimating Chinese strength are very high. During this time, opponents are essentially compelled to hedge, regardless of whether China is genuinely strong or concealing weakness. This scenario

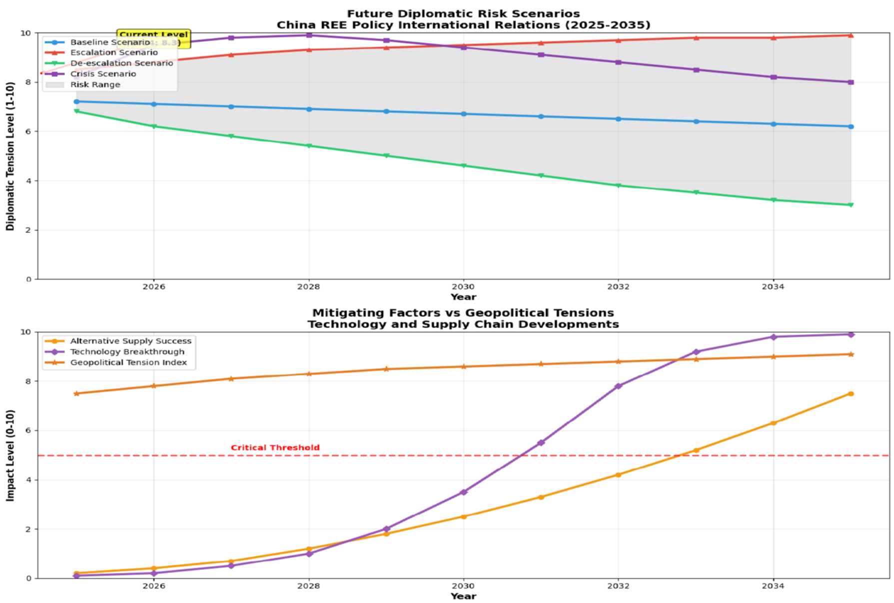

Fig. 7 Mitigating Factors in the China REE Signaling Game (2025–2035)

directly relates to the pooling equilibrium in the formal model, where nondisclosure causes outsiders to act as if China is strong to avoid potential risks.

Figure 7 (bottom panel) further clarifies this by showing mitigation factors such as the success of alternative supply chains and technological breakthroughs. These paths show sharp growth mainly after 2030, indicating that substitutes and new materials need time to become commercially viable. Before then, efforts to diversify remain partial, and technological options are either costly or unproven. As a result, China's influence gradually declines. The forecast suggests that Beijing's ability to signal is strongest in the near term, especially during the late 2020 s and early 2030 s, when uncertainty about alternatives stays high. This supports the model's idea that opacity lengthens the pooling phase, delaying the point when rivals can clearly distinguish real Chinese strength from weakness.

The signaling framework also explains why not all rival responses are equally effective. Stockpiling, for instance, offers immediate relief by increasing inventories and buffering against short-term shocks.

In contrast, costly investments in alternative supply chains or breakthrough technologies—such as permanent magnet recycling or substitute materials—serve as "sinking cost" signals of commitment. These require upfront sacrifices but change the long-term equilibrium by decreasing reliance on China's leverage. The model suggests that only these costly, credible signals can effectively shift the balance of power over time. This aligns with insights from Schelling [38] and Slantchev [40], but extends them into the economic sphere, where credibility is judged not by troop deployments or sanctions, but by irreversible industrial investments.

This logic highlights the delayed aspect of strategic adjustment. Rivals can weaken Chinese coercion, but only at a cost and after a delay. The late 2020 s and early 2030 s thus form a structural bottleneck: rivals must invest heavily without immediate benefits, while China has a window during which its opacity-based signals are most credible. This dynamic explains why escalation and crisis scenarios tend to align around the early 2030 s before diverging depending on whether costly rival signals eventually succeed in changing the equilibrium. The main contribution here is to show that opacity can alter the timing of pressure, postponing the point at which rival costly signals start to matter.

Another insight relates to expanding opacity as a strategic signal. In addition to quota nondisclosure, China is likely to extend informational concealment into related areas such as patents, midstream technological processes, and standards. This aligns with China's broader Export Control Law, which limits strategic technologies [35].

Recent developments reinforce this extension of opacity into patents and knowledge domains. Chinese regulators tightened rare earth export licensing rules, requiring firms to disclose highly sensitive information such as production flows, images of facilities, and client lists, while also mandating registration of technical experts and, in some cases, withholding passports from key staff [12, 42]. These measures do not reduce physical supply but instead restrict the visibility of industrial processes and innovation paths, increasing the difficulty for rivals to monitor or replicate Chinese advances.

The shift demonstrates that informational denial is not limited to quotas; it is increasingly embedded in export administration and intellectual property practices, consistent with the model's prediction that opacity becomes a lasting tool of leverage.

By withholding or classifying rare earth–related intellectual property, Beijing can create a pooling equilibrium where outsiders cannot distinguish between genuine breakthroughs and strategic bluffing. This mechanism keeps uncertainty alive and forces rivals to assume worst-case scenarios, leading to defensive over-investment. Although not explicitly shown in Figs. 6 or 8, this informational aspect is the key driver behind China's power even as material advantages decline. It also broadens the coercion literature by showing that nondisclosure itself—not just material restrictions—can serve as a lasting tool of statecraft.

The cumulative conclusion of these predictive scenarios is twofold. In the short to medium term, China's opacity strategy ensures that its coercive signals remain credible and costly to ignore. This advantage peaks around 2030–2032, when rivals are still in the process of scaling alternatives but have not yet produced credible countersignals. In the longer term, however, the very logic of signaling predicts that costly rival investments will erode China's dominance.

Diversification, recycling, and technological innovation eventually shift the equilibrium away from escalation, though only after a delay. The critical contribution of this analysis is to demonstrate how the signaling game framework reconciles resource politics and coercion theory: opacity creates a pooling equilibrium that magnifies short-term risks, while costly rival signals eventually reestablish separation and undermine coercion.

In this way, the predictive scenarios are directly linked to the literature. Resource dependency accounts [18, 50] correctly emphasized the disruptive potential of supply shocks but overlooked the informational channel. Strategic trade analyses [23] rightly highlighted industrial policy but assumed transparent markets. IR coercion theory [38, 39] was accurate in its assessment of credibility but focused almost entirely on military tools. By integrating these strands into a unified signaling framework, this paper advances coercion studies by showing how opacity itself can be weaponized as a substitute for material denial [47]. The forecasting exercise emphasizes not just the ongoing influence of Chinese leverage but also the need to model nondisclosure as a coercive signal.

Yet, the credibility of future rival signals will depend not only on costly investments but also on whether governments avoid repeating structural mistakes. The U.S. example shows that resilience is as much about fixing domestic weaknesses as it is about countering Chinese opacity. Much of the literature interprets China's dominance mainly through strategic statecraft—quotas, export restrictions, or industrial consolidation—but Park, Tracy, and Ewing [34] demonstrate that the collapse of U.S. rare earth capacity largely resulted from domestic failures.

Environmental liabilities, regulatory fragmentation, short-term corporate incentives, and the transfer of intellectual property abroad weakened the American industry long before Beijing gained global market share. This view complicates the common "China versus the West" narrative and shows that rebuilding credibility will require the U.S. to fix its own institutional issues while preparing for China's continued strategic use of quotas and opacity.

Patent Opacity as a Future Leverage Signal

An important extension of the signaling model involves intellectual property. Over 80% of China's patents related to rare earths are filed domestically in Chinese, with limited visibility in international databases and minimal licensing to foreign companies. China's restrictions on technology exports further limit access to these patents [30]. Even with current practices, this means that competitors already face informational barriers in understanding Chinese technological capacity.

The model predicts that this opacity will increase. As the U.S. and other governments launch initiatives to expand rare earth mining, processing, and recycling, Beijing has strong incentives to restrict the spread of technical knowledge even more. One likely approach is increased classification or withholding of patents, especially those related to midstream processing and permanent magnet production.

Formally, this extension follows the same logic as quota nondisclosure. Just as withholding production quotas maintains a pooling equilibrium where outsiders must hedge against China's strength, withholding patents creates a similar pooling situation in technology. Rivals cannot distinguish real breakthroughs from strategic bluffing and must assume the worst. This results in costly defensive actions—such as duplicate R&D, increased subsidies, and over-investment in alternatives—even if China's actual lead is smaller than believed. The secrecy of intellectual property thus becomes a structural amplifier of coercive power: it raises the expected cost of pressuring while leaving Beijing's actual position unchanged.

Integrating patents into the signaling framework strengthens the contribution to the literature. Resource dependency accounts [18, 50] analyzed volume shocks but ignored informational denial. Strategic trade theory [3, 23] highlighted industrial subsidies but assumed transparent technology diffusion. Coercion theory [38, 40] stressed credibility but focused on observable military or economic moves. By showing that nondisclosure of patents can function like nondisclosure of quotas, this paper demonstrates that informational opacity is not an isolated tactic but a generalizable coercive strategy.

In predictive terms, the message is clear: China's REE leverage will last longer than market trends alone suggest. Even as alternative supplies and new technologies emerge after 2030, opacity in patents prevents rivals from fully discerning China's true capacity from its signaling. Although China leads in REE patent filings, its secrecy forces competitors to assume a technological advantage [24]. This delays the decline of Beijing's coercive power and prolongs the period of higher risk. China's emphasis on high-quality REE patents, often kept confidential, increases this opacity [46]. Thus, the patent system acts both as a continuation of authoritarian information control [17, 25] and as an extension of coercion theory into new informational domains.

Conclusion

This paper began with a puzzle: why would Beijing abandon three decades of transparent quota announcements and shift to a nondisclosure regime? Existing explanations of rare earths emphasized price manipulation, export bans, or physical chokepoints. None accounted for the informational dimension. By formalizing the problem as a signaling game, I demonstrated that opacity itself generates coercive leverage. In a pooling equilibrium, foreign actors cannot distinguish strength from weakness; they must behave as if China is strong, incurring costs even when Beijing may be constrained. The model therefore explains why withholding information—rather than overt restriction—becomes the rational strategy.

The rare earth case shows that leverage doesn't need volume cuts or price manipulation. Managing expectations can replace the need for control overflows. The formal model clarifies this: nondisclosure changes belief updates, raises the threshold, and makes rivals engage in costly hedging. Opacity avoids the legal risks of overt restrictions, as seen in the WTO's 2014 ruling against China's export measures [49]. What seems like silence is a deliberate signal within an equilibrium framework. This shifts the view of rare earths from just a resource weapon to a tool for informational statecraft.

The contribution spans three literatures. Resource politics identified vulnerability but assumed transparent quantities [18, 50]. Strategic trade theory emphasized industrial policy and subsidies [3, 23] but assumed observable market signals. Coercion theory highlighted credibility and costly signaling [38, 40] but mostly focused on military threats. By combining these strands, this paper develops a theory of informational coercion where opacity itself acts as a credible signal. It demonstrates that nondisclosure can generate equilibria like threats, even without overt actions.

The model also shows how predictive scope works. If opacity maintains its leverage in quotas, it is likely to expand into patents, midstream processing technologies, and industrial standards. Already, more than 80% of patents related to rare earths are filed domestically in Chinese, creating significant barriers for foreign access. As the United States and its allies accelerate their initiatives in rare earth and semiconductor research, Beijing has both the motivation and the ability to limit international transparency. Withholding or classifying patents would lead to the same pooling effect: outsiders cannot tell genuine breakthroughs from strategic bluffing and are forced to assume the worst. This informational denial extends the logic of coercion beyond quotas into the governance of technology itself.

This general mechanism—where opacity replaces material restrictions—broadens the study of coercion. Schelling's insight that coercion relies on credibility, and Slantchev's refinement that credibility depends on beliefs under incomplete information, are extended into the economic field. The case of rare earths demonstrates that credible coercion can emerge not from observable threats but from signals that are intentionally withheld. This insight links international political economy to the literature on authoritarian information control [17], emphasizing that selective transparency plays a role in both domestic governance and global resource competition.

Appendix 1

Table 3 Representative MIIT/MNR Rare Earth Quota Announcements, 2020–2023

Year	Batch	Title (official)	Notice No.	Date	URL (gov.cn/ miit.gov.cn)
2020	First batch	工业和信息化部 自然资源部关于下达2020年第一批稀土开采、冶炼分离总量控制指标的通知	工信部联原〔2020〕27号	2020-07-10	link
2020	Annual total	工业和信息化部 自然资源部关于下达2020年度稀土开采、冶炼分离总量控制指标的通知	工信部联原〔2020〕103号	2020-07-18	link
2021	First batch	工业和信息化部 自然资源部关于下达2021年第一批稀土开采、冶炼分离总量控制指标的通知	工信部联原〔2021〕16号	2021-02-04	link
2021	Annual total	工业和信息化部 自然资源部关于下达2021年度稀土开采、冶炼分离总量控制指标的通知	工信部联原〔2021〕123号	2021-10-08	link
2022	First batch	工业和信息化部 自然资源部关于下达2022年第一批稀土开采、冶炼分离总量控制指标的通知	工信部联原〔2022〕10号	2022-02-10	link
2022	Second batch	工业和信息化部 自然资源部关于下达2022年第二批稀土开采、冶炼分离总量控制指标的通知	工信部联原〔2022〕90号	2022-08-17	link
2023	First batch	工业和信息化部 自然资源部关于下达2023年第一批稀土开采、冶炼分离总量控制指标的通知	工信部联原〔2023〕23号	2023-03-01	link
2023	Second batch	工业和信息化部 自然资源部关于下达2023年第二批稀土开采、冶炼分离总量控制指标的通知	工信部联原〔2023〕159号	2023-09-18	link
2023	Third batch	工业和信息化部 自然资源部关于下达2023年第三批稀土开采、冶炼分离总量控制指标的通知	工信部联原〔2023〕245号	2023-12-14	link

The quota regime is jointly administered by the Ministry of Industry and Information Technology (MIIT) and the Ministry of Natural Resources (MNR). Mining quotas are primarily overseen by MNR, smelting–separation quotas by MIIT, but the joint notices ("工信部联原〔...〕") bundle both. Through 2023, quota announcements were consistently published online and publicly accessible. In 2025, by contrast, the first batch was issued without public disclosure; see *Caixin* [4] and *Reuters* [37] for details

Appendix 2. Formal Analysis of the Signaling Equilibrium

Takeaway: The following proofs formally demonstrate that when China withholds quota information, both strong and weak types prefer opacity, which forces foreign actors to hedge as if China is strong—showing how silence itself becomes a stable source of bargaining power.

B.1 Model Setup and Equilibrium Definition

- **Players and Strategy Spaces:**China's strategy: $\sigma_C: \{Q_H, Q_L\} \rightarrow \Delta(\{D, ND\})$
- Foreign actors' strategy: $\sigma_F: \{D, ND\} \rightarrow \Delta(\{H, P\})$
- Belief system: $\mu: \{D, ND\} \rightarrow [0,1]$ where $\mu(s) = \Pr(Q_H | s)$

Definition 1 (Perfect Bayesian Equilibrium) A PBE consists of strategies (σ_C^*, σ_F^*) and beliefs μ^* such that:

1. **Sequential Rationality (China):** For all $Q \in \{Q_H, Q_L\}$ and $s \in \{D, ND\}$:

$$\sigma_C^*(s \mid Q) > 0 \Rightarrow s \in \arg\max_{s'} \mathbb{E}\left[\pi_C\left(Q, s', \sigma_F^*(s')\right) \mid Q\right]$$

2. **Sequential Rationality (Foreign):** For all $s \in \{D, ND\}$ and $a \in \{H, P\}$:

$$\sigma_F^*(a \mid s) > 0 \Rightarrow a \in \arg\max_{a'} \mathbb{E}\left[\pi_F\left(a', Q\right) \mid s, \mu^*(s)\right]$$

3. **Belief Consistency:** For all s such that $\sum_Q p(Q)\sigma_C^*(s \mid Q) > 0$:

$$\mu^*(s) = \frac{p \cdot \sigma_C^*(s \mid Q_H)}{p \cdot \sigma_C^*(s \mid Q_H) + (1-p) \cdot \sigma_C^*(s \mid Q_L)}$$

4. **Off-Path Beliefs:** Satisfy the Intuitive Criterion [10].

B.2 Foreign Best Response Analysis

Lemma 1 (Foreign Optimal Response) Assume $A < \delta$ (necessary for meaningful threshold). Given belief μafter observing signal s:

- **Above threshold** ($\mu \geq \mu^*$): Hedge because China is likely strong
- **Below threshold** ($\mu < \mu^*$): Press because China is likely weak
- **At threshold** ($\mu = \mu^*$): Indifferent (either action gives same expected payoff)

The threshold $\mu^* = \frac{A+\gamma}{\gamma+\delta}$ is the **critical belief** where foreigners switch strategies.

Proof The expected payoff from pressing is:

$$\mathbb{E}\left[\pi_F(P) \mid \mu\right] = (1-\mu)\gamma - \mu\delta$$

Foreigners prefer hedging iff:

$$\mathbb{E}\left[\pi_F(P) \mid \mu\right] < \pi_F(H) = -A$$

$$\iff (1-\mu)\,\gamma - \mu\delta < -A$$

$$\iff \mu\,(\gamma+\delta) > A+\gamma$$

$$\iff \mu > \frac{A+\gamma}{\gamma+\delta} \equiv \mu^*$$

- **Note on parameter restriction:** $\mu^*\in(0,1)$ requires:$\mu^*>0$: Always satisfied since $A, \gamma, \delta>0$
- $\mu^*<1$: Requires $A+\gamma<\gamma+\delta \Rightarrow A<\delta$

If $A\geq\delta$, then $\mu^*\geq 1$, meaning foreigners always press regardless of beliefs. \qed.

B.3 Pooling Equilibria

Theorem 1 (Pooling ND with Hedging) Suppose $p\geq\mu^*$, $\phi_D\geq 0$, $\kappa\geq 0$, and $A<\delta$. Then there exists a unique PBE where:

- Both types choose *ND*: $\sigma_C^*\,(ND \mid Q_H) = \sigma_C^*\,(ND \mid Q_L) = 1$
- Foreigners hedge after *ND*: $\sigma_F^*\,(H \mid ND) = 1$
- Off-path: $\sigma_F^*\,(H \mid D) = 1$ if Q_H revealed, $\sigma_F^*\,(P \mid D) = 1$ if Q_L revealed

Proof *Step 1: Belief consistency. In pooling ND, both types choose ND with probability 1, so:

$$\mu^*(ND) = \frac{p\cdot 1}{p\cdot 1 + (1-p)\cdot 1} = p$$

*Step 2: Foreign sequential rationality.

Since $p\geq\mu^*$ by assumption, Lemma 1 implies $\sigma_F^*\,(H \mid ND) = 1$. Off-path beliefs under disclosure are type-revealing, so foreigners hedge against Q_H and press against Q_L.

Step 3: China's sequential rationality. We verify no profitable deviations exist.

For Q_H:

- Payoff under *ND*: $\pi_C(Q_H, ND, H) = L_H - C_H$
- Payoff under *D*: $\pi_C(Q_H, D, H) = L_H - C_H - \phi_D$
- No deviation since $\phi_D\geq 0$

For Q_L:

- Payoff under ND: $\pi_C(Q_L, ND, H) = L_L - C_L$
- Payoff under D: $\pi_C(Q_L, D, P) = L_L - C_L - \phi_D - \kappa$
- No deviation since $\phi_D \geq 0$ and $\kappa \geq 0$\qed

Theorem 2 (Pooling ND with Pressing) Suppose $p \leq \mu^*$, $\phi_D > 0$, $\kappa \leq \phi_D$, and $A < \delta$. Then there exists a PBE where both types choose ND and foreigners press.

Proof *Step 1: Belief and foreign response. $\mu^*(ND) = p \leq \mu^*$ implies $\sigma_F^*(P \mid ND) = 1$ by Lemma 1.

Step 2: China's incentive compatibility.
For Q_L:

- Payoff under ND: $\pi_C(Q_L, ND, P) = L_L - C_L - \kappa$
- Payoff under D: $\pi_C(Q_L, D, P) = L_L - C_L - \phi_D - \kappa$
- Prefers ND since $\phi_D > 0$

For Q_H:

- Payoff under ND: $\pi_C(Q_H, ND, P) = L_H - C_H - \kappa$
- Payoff under D: $\pi_C(Q_H, D, H) = L_H - C_H - \phi_D$
- Prefers ND iff $\kappa \leq \phi_D$ (given)

Thus, both types choose ND.

B.4 Separating Equilibria

Theorem 3 (Separating Equilibrium) Suppose $\kappa = \phi_D > 0$ and $A < \delta$. Then there exists a separating PBE where:

- High type discloses: $\sigma_C^*(D \mid Q_H) = 1$
- Low type pools: $\sigma_C^*(ND \mid Q_L) = 1$
- $\sigma_F^*(H \mid D) = 1$, $\sigma_F^*(P \mid ND) = 1$

- Proof *Step 1: Beliefs.* Under separation:$\mu^*(D) = 1$ (only Q_H discloses)
- $\mu^*(ND) = 0$ (only Q_L withholds)

- *Step 2: Foreign responses.* $\mu^*(D) = 1 > \mu^* \implies \sigma_F^*(H \mid D) = 1$
- $\mu^*(ND) = 0 < \mu^* \implies \sigma_F^*(P \mid ND) = 1$

Step 3: Incentive compatibility.
For Q_H:

- Payoff under D: $L_H - C_H - \phi_D$
- Payoff from deviating to ND: $L_H - C_H - \kappa$
- Prefers D iff $\phi_D \leq \kappa$

For Q_L:

- Payoff under ND: $L_L - C_L - \kappa$
- Payoff from deviating to D: Since D is on-path for Q_H, foreigners respond with H, so $\pi_C(Q_L, D, H) = L_L - C_L - \phi_D$
- Prefers ND iff $\kappa \leq \phi_D$

- *Step 4: Existence condition.* Both ICs require:Q_H: $\phi_D \leq \kappa$
- Q_L: $\kappa \leq \phi_D$

These are compatible only when $\kappa = \phi_D$.

Proposition 1 (No "Low Discloses" Equilibrium) There exists no PBE where only the low type discloses.

Proof Suppose $\sigma_C^*(D \mid Q_L) = 1$ and $\sigma_C^*(ND \mid Q_H) = 1$. Then:

- $\mu^*(D) = 0 \Rightarrow \sigma_F^*(P \mid D) = 1$
- For Q_L: payoff under D is $L_L - C_L - \phi_D - \kappa$ vs. potentially $L_L - C_L - \kappa$ or $L_L - C_L$ under ND
- Since $\phi_D > 0$, the low type always prefers ND, contradicting the proposed equilibrium.

A.5 Existence and Uniqueness (Corrected)

Theorem 4 (Complete Characterization) For any parameter vector $(A, \gamma, \delta, \phi_D, \kappa, p)$ with $A < \delta$:

1. **If $p > \mu^*$:** Unique **Pooling ND (Hedge)** equilibrium exists

2. **If $p < \mu^*$:**If $\kappa < \phi_D$ and $\kappa > 0$: Unique **Pooling ND (Press)** equilibrium exists
   If $\kappa = \phi_D$ and $\kappa > 0$: **Both** the **Pooling ND (Press)** and **Separating** equilibria exist (multiplicity)
   If $\kappa > \phi_D$: No pure-strategy equilibrium exists under these conditions

3. **If** $p = \mu^*$**:** Boundary case—semi-separating equilibria possible

- Proof **Case 1** follows from Theorem 1
- **Case 2a** follows from Theorem 2: when $\kappa < \phi_D$, only pooling ND with pressing satisfies all incentive constraints
- **Case 2b** follows from Theorems 2 and 3: when $\kappa = \phi_D$, both equilibria satisfy their respective incentive compatibility conditions
- **Case 2c**: When $\kappa > \phi_D$, Theorem 2's condition $\kappa \leq \phi_D$ is violated, so pooling ND with pressing fails. Theorem 3's condition $\kappa = \phi_D$ is also violated, so separating fails. The high type would prefer to deviate from any proposed pooling strategy when pressing costs exceed disclosure costs.

B.6 Comparative Statics

Proposition 2 (Threshold Sensitivity) The belief threshold $\mu^* = \frac{A+\gamma}{\gamma+\delta}$ (satisfies)

$$\frac{\partial \mu^*}{\partial A} = \frac{1}{\gamma + \delta} > 0$$

$$\frac{\partial \mu^*}{\partial \delta} = -\frac{A + \gamma}{(\gamma + \delta)^2} < 0$$

A.7 Welfare Analysis

Proposition 3 (China's Welfare Ranking) China's expected payoffs satisfy:

$$\mathbb{E}\left[\pi_C \mid \text{Pooling ND}, \text{Hedge}\right] > \mathbb{E}\left[\pi_C \mid \text{Separating}\right] = \mathbb{E}\left[\pi_C \mid \text{Pooling ND}, \text{Press}\right]$$

when the respective equilibria exist.

- Proof **Pooling ND with Hedging:** $\mathbb{E}\left[\pi_C\right] = p\left(L_H - C_H\right) + (1-p)\left(L_L - C_L\right)$
- **Separating (when** $\kappa = \phi_D$**):** $\mathbb{E}\left[\pi_C\right] = p\left(L_H - C_H - \phi_D\right) + (1-p)\left(L_L - C_L - \kappa\right) = p\left(L_H - C_H - \kappa\right) + (1-p)\left(L_L - C_L - \kappa\right)$
- **Pooling ND with Pressing:** $\mathbb{E}\left[\pi_C\right] = p\left(L_H - C_H - \kappa\right) + (1-p)\left(L_L - C_L - \kappa\right)$

Under the equilibrium condition $\kappa = \phi_D$, the separating and pooling ND with pressing equilibria yield identical expected payoffs. The ranking shows pooling ND with hedging dominates both, but the other two are equivalent.

Appendix 3

Table 4 Representative Stockpiling and Policy Responses on Rare Earths (Japan, EU, U.S.)

Jurisdiction	Policy Instrument/Data Source	Issuing Body/Platform	Date/Access	Notes/URL
Japan	Rare metals stockpiling program overview ("Stockpiling: Metals")	JOGMEC	n.d., accessed August 2025	JOGMEC Stockpiling: Metals
HRE supply agreement (Lynas & Sojitz)	JOGMEC	Mar 7, 2023	JOGMEC press release	
Japan–France alternative REE cooperation	METI	Mar 17, 2025	METI press release	
European Union	Rare Earth Magnets & Motors: A European call for action	ERMA (European Commission)	2021	ERMA report
Critical Raw Materials Act (Reg. 2024/1252)	EU Parliament & Council	Apr 11, 2024	EUR-Lex text	
United States	DPA Title III award to MP Materials	DoD	Nov 17, 2020	DoD press release
DPA Title III award to Lynas USA	DoD	Feb 1, 2021	DoD press release	
Contract for domestic heavy REE separation	OUSD IBP (DoD)	Sep 19, 2023	DoD IBP release	
DOE actions on critical minerals & materials	DOE	2025	DOE announcement	
Market Data (volatility)	Neodymium oxide price series (daily historical)	Shanghai Metals Market (SMM)	Start date: Dec 25, 2006 – present	SMM Neodymium price
Neodymium & Dysprosium price indices	Asian Metal	Accessed August 2025	Asian Metal Neodymium index, Dysprosium index	
Commodity volatility of ETMs study	Bastianin, Li & Shamsudin	2025	arXiv preprint	

Japan's stockpiling regime is administered through JOGMEC under METI oversight and has been a cornerstone of supply security since the 1980s

The EU's 2024 Critical Raw Materials Act represents the first binding legal framework for rare earth supply security, complemented by ERMA's strategic alliance initiatives

The U.S. has leaned heavily on DPA Title III awards and DoE supply-chain programs to create domestic separation and magnet capaci

Appendix 4. Diversification Costs, Variance Decomposition, and Robustness Checks

The three supplementary appendix figures show that the empirical relationship is robust, diversification is costly, and variance decomposition reinforces China's structural advantage. They serve as technical validation and elaboration, ensuring the main narrative (Figs. 3, 4, and 5) remains focused while supplying the depth reviewers will expect.

Figs. 8, 9, and 10 provide robustness checks on the correlation between policy intensity and REE prices, complementing the principal regression in Fig. 2. The residual analysis confirms the stability of the estimated relationship, with no evidence of systematic bias or structural breaks. By demonstrating consistent predictive performance across multiple specifications, this robustness test reassures readers that the observed policy–price linkage is not a spurious correlation.

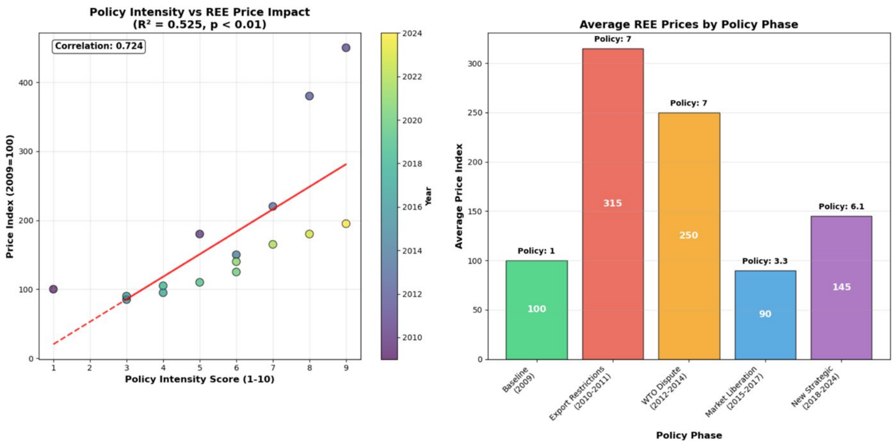

Fig. 8 Policy and prices

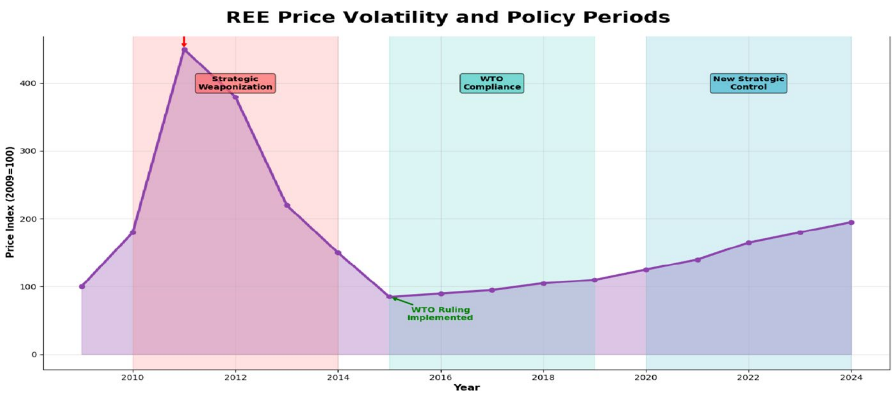

Fig. 9 REE price volatility

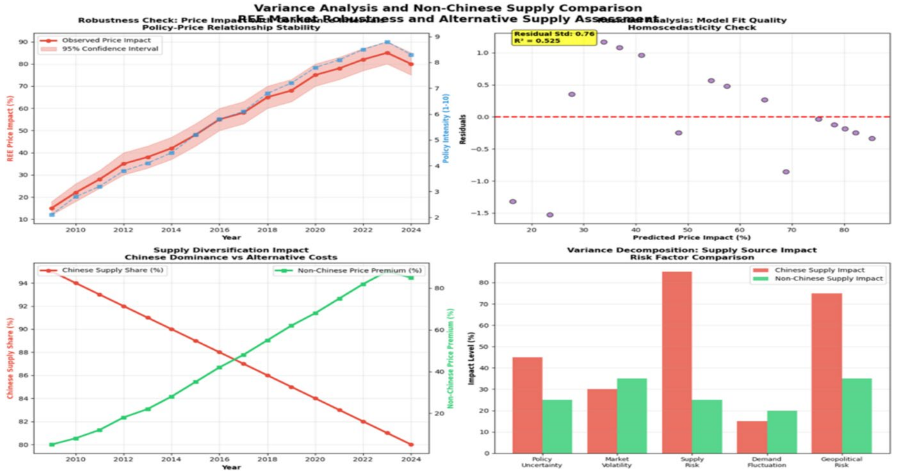

Fig. 10 Variance analysis

This supports the game-theoretic logic of credible signaling—the price channel is not random noise but a consistent function of Chinese policy intensity.

This figure examines the trade-offs associated with reducing dependence on Chinese REE supply. The analysis shows that as Chinese market share falls, alternative sourcing carries a rising price premium. Even as diversification reduces exposure to Chinese policy shocks, it imposes structural adjustment costs that followers must bear.

This reflects the *second-best dilemma* in the follower's strategy: hedging against Chinese dominance entails measurable economic costs, which China can anticipate and exploit in its sequencing game.

This multi-panel figure combines robustness checks and variance decomposition to assess Chinese versus non-Chinese supply dynamics:

- Panel A validates the policy–price time-series relationship with confidence intervals.
- Panel B confirms model fit quality through residual analysis.
- Panel C illustrates the inverse relationship between declining Chinese supply share and rising non-Chinese cost premiums.
- Panel D decomposes supply risks, showing that China dominates in supply security and geopolitical risk channels, while non-Chinese suppliers contribute disproportionately to volatility and price instability.

This decomposition highlights the **structural asymmetry** in the game: even when followers diversify, the risk allocation remains skewed in China's favor, reinforcing its ability to impose costs and extract concessions.

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Data Availability This comprehensive dataset on China's Rare Earth Elements (REE) policies and their international diplomatic effects represents a unique compilation of quantitative metrics spanning 2009–2024, with projections extending to 2035. The dataset encompasses multiple analytical dimensions, including policy intensity scores (1–10 scale), REE price impact percentages, diplomatic tension indices, supply chain diversification metrics, and future risk assessments across ten critical categories. Available for download at https://julius.ai/files

Declarations

Conflict of interest The author declares that he has no conflicts of interest.

References

1. Baker Institute. 2022. *China's rare earths and U.S. policy options*. Houston: Rice University Baker Institute for Public Policy Available at: https://www.bakerinstitute.org.
2. Blair, Alex. 2025. "China's trump card: Using rare earth elements as geopolitical bargaining chips." Mining Technology (August). https://www.mining-technology.com/features/chinas-trump-card-rare-earth-elements/?cf-view
3. Brander, James A.., and Barbara J.. Spencer. 1985. Export subsidies and international market share rivalry. *Journal of International Economics* 18 (1–2): 83–100. https://doi.org/10.1016/0022-1996(85)90006-6.
4. Caixin. 2025. China issues 2025 rare earth mining and smelting quotas without public disclosure. Caixin Global, August 6. Available at: https://www.ctia.com.cn/en/news/43678.html
5. Center for Strategic and International Studies (CSIS). 2025. *The consequences of China's new rare earths export restrictions*. Washington, DC: CSIS Available at: https://www.csis.org/analysis/consequences-chinas-new-rare-earths-export-restrictions.
6. Chapman, Bert. 2018. The geopolitics of rare earth elements: Emerging challenge for U.S. national security and economics. *Journal of Self-Governance and Management Economics* 6 (2): 50–91. https://doi.org/10.22381/JSME6220183.
7. Chen, et al. 2024. Interdependence in the supply of rare earth elements between China and the United States helps stabilize global supply chains. *One Earth* 7:242–252. https://doi.org/10.1016/j.oneear.2024.01.011.
8. Cheung, Yin-Wong, and Xingwang Qian. 2009. Hoarding of international reserves: Mrs. Machlup's wardrobe and the joneses. *Review of International Economics* 17 (4): 777–802. https://doi.org/10.1111/j.1467-9396.2009.00843.x.

9. Chinese Ministry of Commerce and the Ministry of Science and Technology. 2023. *Revised catalogue of technologies prohibited or restricted from export*. Beijing: People's Republic of China https://cset.georgetown.edu/publication/china-export-control-catalog-2023/.
10. Cho, In-Koo., and David M.. Kreps. 1987. Signaling games and stable equilibria. *Quarterly Journal of Economics* 102 (2): 179–221. https://doi.org/10.2307/1885060.
11. Colgan, Jeff D.. 2014. *Petro-aggression: When oil causes war*. New York: Cambridge University Press.
12. Enmont, Jon, Heather Somerville, and Alistair MacDonald. 2025. China to block its rare-earth experts from spilling their secrets. *Wall Street Journal* July 26. Available at: https://www.wsj.com/world/china-to-block-its-rare-earth-experts-from-spilling-their-secrets-8d69b75f.
13. Farrell, Henry, and Abraham L.. Newman. 2019. Weaponized interdependence: How global economic networks shape state coercion. *International Security* 44 (1): 42–79. https://doi.org/10.1162/isec_a_00351.
14. Fearon, James D.. 1997. Signaling foreign policy interests: Tying hands versus sinking costs. *Journal of Conflict Resolution* 41 (1): 68–90. https://doi.org/10.1177/0022002797041001004.
15. Fojtíková, L., K. Pekarčíková, R. Sousedíková, et al. 2025. Determinants of critical raw material imports: The case of the European Union and China. *Mineral Economics*. https://doi.org/10.1007/s13563-025-00528-4.
16. Grohol, M., and C. Veeh. 2023. *Study on critical raw materials for the EU 2023*. Brussels: European Commission Working Paper https://op.europa.eu/en/publication-detail/-/publication/57318397-fdd4-11ed-a05c-01aa75ed71a1.
17. Hollyer, James R., B. Peter Rosendorff, and James R. Vreeland. 2015. Transparency, protest, and autocratic instability. *American Political Science Review* 109 (4): 764–784. https://doi.org/10.1017/S0003055415000412.
18. Humphries, Marc. 2013. *Rare earth elements: The global supply chain*. Washington, DC: Congressional Research Service.
19. Islam, M. 2025. Chinese rare earth exports and US military industry: Do governance mechanisms de-escalate strategic rivalry? *Chinese Political Science Review*. https://doi.org/10.1007/s41111-025-00289-6.
20. Kalantzakos, Sophia. 2018. *China and the geopolitics of rare earths*. Oxford: Oxford University Press.
21. Kim, Y., and S. Rho. 2024. The US–China chip war, economy–security nexus, and Asia. *Journal of Chinese Political Science* 29:433–460. https://doi.org/10.1007/s11366-024-09871-9.
22. Kobayashi, Yuki. 2025. "China's Rare Earth Export Restrictions and Other Countries' Responses: Strategies for the Main Battleground of Economic Security." SPF China Observer, July 9. Sasakawa Peace Foundation. https://www.spf.org/spf-china-observer/en/document-detail062.html. Accessed 6 October 2025.
23. Lee, Jeong-Dong, and Jin-Ho Wen. 2019. China's rare earth policy and its implications for global supply security. *Resources Policy* 62:319–326. https://doi.org/10.1016/j.resourpol.2019.02.002.
24. LexisNexis. 2024. China leads in rare earth elements, yet portfolio strength lags. Available at: https://www.lexisnexis.com/community/insights/legal/patent/b/china-leads-in-rare-earth-elements-yet-portfolio-strength-lags
25. Lorentzen, Peter L.. 2014. China's strategic censorship. *American Journal of Political Science* 58 (2): 402–414. https://doi.org/10.1111/ajps.12065.
26. Lu, C. 2021. Why rare earths are the key to just about everything. Foreign Policy, April 22. Available at: https://foreignpolicy.com/2021/04/22/rare-earths-china-us-greenland-geopolitics
27. Mancheri, N. 2012. Chinese monopoly in rare earth elements: Supply–demand and industrial applications. *China Report* 48 (4): 449–468. https://doi.org/10.1177/0009445512466621.
28. Mancheri, N., B. Sprecher, G. Bailey, J. Ge, and A. Tukker. 2019. The effect of Chinese policies on rare earth supply chain resilience. *Resources, Conservation and Recycling* 142:101–112. https://doi.org/10.1016/j.resconrec.2018.11.017.
29. Massot, Pascale. 2025. The China challenge in critical minerals: The case for asymmetric resilience. The Diplomat, June. Available at: https://thediplomat.com/2025/06/the-china-challenge-in-critical-minerals
30. Ministry of Commerce of the People's Republic of China (MOFCOM). 2023. *General announcement no. 23*. Beijing: PRC https://globaltradealert.org/state-act/76184-china-government-announces-export-control-measures-for-gallium-and-germanium.

31. Maskus, Keith E., and Stephen A. Merrill, eds. 2019. *Innovation, intellectual property, and development: A better set of approaches for the 21st century*. Cambridge: Cambridge University Press.
32. Morrow, James D.. 1999. The strategic setting of choices: Signaling, commitment, and negotiation in international politics. In *Strategic choice and international relations*, ed. David A.. Lake and Robert Powell, 77–114. Princeton, NJ: Princeton University Press.
33. Oxford Institute for Energy Studies. 2023. *China's dominance in rare earths and policy responses*. Oxford: OIES.
34. Park, Sulgiye, Cameron L. Tracy, and Rodney C. Ewing. 2023. Reimagining US rare earth production: Domestic failures and the decline of US rare earth dominance—Lessons learned and recommendations. *Resources Policy* 85:104022. https://doi.org/10.1016/j.resourpol.2023.104022.
35. People's Republic of China. 2020. *Export control law of the people's republic of China*. Beijing: National People's Congress http://en.npc.gov.cn.cdurl.cn/2020-10/17/c_689302.htm.
36. Onstad, Eric, and Amy Lv. 2025. Rare earth prices hit two-year peak after MP materials stops China shipments. Reuters, August 26. Available at: https://www.reuters.com
37. Reuters. 2025. China quietly issues first 2025 rare earth mining and smelting quotas without public statement. Reuters, July 18. Available at: https://www.reuters.com/world/china/china-quietly-issues-2025-rare-earth-quotas-sources-say-2025-07-18
38. Schelling, Thomas C.. 1966. *Arms and influence*. New Haven, CT: Yale University Press.
39. Sechser, Todd S.. 2017. *Atomic advantage: Nuclear monopoly and the future of nuclear deterrence*. Ithaca, NY: Cornell University Press.
40. Slantchev, Branislav L. 2005. Military coercion in interstate crises. *American Political Science Review* 99 (4): 533–547. https://doi.org/10.1017/S0003055405051887.
41. Shen, Y., R. Moomy, and R.G. Eggert. 2020. China's public policies toward rare earths, 1975–2018. *Mineral Economics* 33: 127–151. https://doi.org/10.1007/s13563-019-00214-2.
42. Shepherd, Christian, and Harry Dempsey. 2025. China rare earth export rules spark alarm over IP exposure. Financial Times, July 18. Available at: https://www.ft.com/content/0fce7177-a713-4c06-ba22-0ae429efe73f
43. Vekasi, K. 2019. Politics, markets, and rare commodities: Responses to Chinese rare earth policy. *Japanese Journal of Political Science* 20 (1): 2–20. https://doi.org/10.1017/S1468109918000373.
44. Vekasi, K. 2023. Securing supply chain resiliency for critical rare earth metals. In *Critical minerals, the climate crisis and the tech imperium, Archimedes*, vol. 65, ed. Sophia Kalantzakos, 41–64. Cham: Springer. https://doi.org/10.1007/978-3-031-25577-9_3.
45. Center, Wilson. 2019. *The rare earths trade dispute: Options for the United States*. Washington, DC: Wilson Center.
46. Wininger, A. 2023. China's quantity-to-quality shift in patents continues trend in 2023 Q3. China IP Law Update, October 20. Available at: https://www.natlawreview.com/article/china-patents-quantity-quality
47. Woods, Dwayne. 2024. The silicon sword hanging over China's head. *Journal of Chinese Political Science* 29: 559–590. https://doi.org/10.1007/s11366-024-09883-5.
48. World Economic Forum. 2024. Critical minerals are the key to 21st-century tech. World Economic Forum, August. Available at: https://www.weforum.org/agenda/2024/08/critical-minerals-key-21st-century-tech
49. World Trade Organization (WTO). 2014. *China – Measures related to the exportation of rare earths, tungsten, and molybdenum (DS431): Appellate body and panel reports adopted on 29 august 2014*. Geneva: WTO Available at: https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds431_e.htm.
50. Wübbeke, Jörn. 2013. Rare earth elements in China: Policies and narratives of reinventing an industry. *Resources Policy* 38 (3): 384–394. https://doi.org/10.1016/j.resourpol.2013.05.005.

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