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RESEARCH ARTICLE

AI, Rare Earths, and the Geopolitical Algorithm: Strategic Intersections of India, China, and the U.S. in the 21st Century Tech Race

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Abstract

Artificial Intelligence (AI) has transcended its origins as a technological innovation to become an indispensable pillar underpinning 21st-century economic dynamism, national security architectures, and the evolving contours of international competitiveness. While public and scholarly discourses predominantly emphasize data algorithms, machine learning paradigms, and software advancements, the material substratum of AI's rapid evolution remains underexplored. At the core of AI's hardware ecosystem lie rare earth elements (REEs)—a suite of 17 critical minerals that enable the functioning of semiconductors, advanced computing infrastructures, quantum processors, and renewable energy technologies vital to AI scalability.

This paper interrogates the multidimensional and complex interdependence between AI proliferation and the geopolitics of REE supply chains, with a nuanced focus on the strategic triad of India, China, and the United States. China's hegemony over global REE mining and processing—commanding approximately 60% of extraction and a staggering 85% of refining capacity—has bestowed upon Beijing a formidable leverage in resource politics. This monopolization raises significant implications for the technological sovereignty of AI-reliant economies. In response, the United States and India have embarked upon diversification trajectories, encompassing policy recalibrations, technological innovations, and plurilateral partnerships aimed at mitigating asymmetric dependencies and fostering resilient, autonomous AI infrastructures.

Employing an interdisciplinary analytical framework, this study critically evaluates recent policy architectures, bilateral and multilateral trade alignments, and state-backed technological investments. It draws upon empirical data and comparative case studies to elucidate how resource geopolitics and AI aspirations are converging to recalibrate global power hierarchies in 2025 and beyond. Furthermore, the paper articulates a forward-looking paradigm advocating for multilateral governance mechanisms, emphasizing sustainable resource stewardship, ethical technological collaboration, and the construction of resilient and diversified supply chains to safeguard technological futures.

1. Introduction

Artificial Intelligence (AI) has moved far beyond its early days as a niche computational experiment. Today, it stands as a defining force that is reshaping economic growth models, public governance systems, and global power dynamics in the 21st century. Once confined to laboratories and academic debates, AI is now central to how nations define and project power—enhancing efficiency in governance, transforming healthcare, boosting industrial productivity, and modernizing defense strategies. In this context, AI is no longer just a tool for improving systems—it has become a key driver of influence, deterrence, and strategic dominance. The global race to master AI is thus not merely about technological prowess but about asserting leadership in a changing world order.

While policy and academic discussions have often focused on the software aspects of AI—such as algorithms, data systems, and machine learning—there is a crucial material foundation that remains less examined. This involves rare earth elements (REEs), a group of 17 metallic elements vital for building the physical components of AI systems. These include semiconductors, sensors, magnets, and energy storage devices. REEs are also indispensable for renewable energy, space technologies, and next-generation weapons systems, making them essential not just for economic competitiveness but also for national security. Their use across civilian and military domains gives them a unique strategic value, turning them into powerful instruments of geopolitical influence.

As of 2025, the global REE market is marked by sharp imbalances. China controls about 60% of global REE mining and nearly 85% of processing capacity (Center for Strategic and International Studies, The Consequences of China's New Rare Earths Export Restrictions, 2025). This dominance is the result of long-term policy planning and heavy state investment, rather than mere coincidence. China's near-monopoly allows it to use REEs as a tool of strategic leverage—restricting exports during diplomatic disputes or trade tensions. This tactic highlights a realist approach to international politics, where control over critical resources becomes a means to exert pressure and shape the behavior of other states.

In response, both the United States and India have launched national strategies to reduce their dependence on Chinese supply chains. The U.S. has focused on diversifying its sources, reviving domestic mining, building strategic reserves, and forming alliances with trusted partners. Federal support for REE technology development and public-private collaboration are at the heart of this strategy. American tech companies are also exploring alternatives to REEs, including recycling and circular economy models, blending innovation with state-backed planning—an approach that reflects a blend of defensive realism and techno-nationalism.

India, too, has taken strategic steps to secure its place in the emerging AI–REE landscape. Through initiatives like the Critical Minerals Mission, it is tapping into its own REE reserves, especially in coastal regions rich in monazite sands. Beyond mining, India is also engaging with international partners under frameworks like the U.S.–India Initiative on Critical and Emerging Technologies (iCET). This cooperation aims to build ethical, resilient, and sustainable supply chains. India's strategy showcases a liberal institutionalist approach—emphasizing collaboration over confrontation and rules-based global engagement, even amid systemic rivalries.

The interplay between India, China, and the U.S. reflects broader trends in how global power is being reconfigured. As nations compete over AI capabilities, their control over REE resources has become equally important. Supply chains are being weaponized, alliances are being reshaped, and strategic policymaking increasingly revolves around the material foundations of innovation. Dominance in digital technologies now depends as much on access to physical materials as on advances in software and data science.

This article explores the complex relationship between AI and REEs through the lens of this trilateral dynamic. Using recent policies, trade patterns, and national strategies, it examines how these countries navigate the intersection of technological ambition and geopolitical competition. The research integrates insights from realism, techno-nationalism, and liberal institutionalism to understand how resource politics and innovation are reshaping global structures of power.

In doing so, it contributes to a growing body of scholarship that goes beyond purely technological discussions. It highlights the material geopolitics of innovation, the emerging competition over resource sovereignty, and the potential for cooperative governance in an increasingly divided world. This inquiry is timely not just for policymakers concerned with security and strategy, but also for those engaging with the broader transformations shaping the global digital era.

2. Experimental or Materials and Methods

2.1 Actors

The principal actors constituting the analytical framework of this study are the state apparatuses and technological ecosystems of the People's Republic of China, the United States of America, and the Republic of India. These states were selected based on their commanding roles in shaping both the global Artificial Intelligence (AI) innovation frontier and the rare earth element (REE) geopolitical architecture. Each actor demonstrates distinct technological capabilities, resource endowments, industrial policy paradigms, and geostrategic orientations, offering a comparative triad through which AI-REE interdependencies can be critically examined.

Secondary actors include multinational technology conglomerates, REE mining and processing consortia, plurilateral policy coalitions such as the Quadrilateral Security Dialogue (Quad) and the Minerals Security Partnership (MSP), and international regulatory frameworks concerned with critical mineral trade, environmental stewardship, and technology transfer governance. These entities, although non-state actors, exert significant influence in operationalizing and shaping the material, technological, and political outcomes of AI and REE strategies.

2.2 Measures

The study operationalizes a set of qualitative indicators to assess the intersections between national policy actions, technological investments, and the evolving geopolitics of AI and REEs. The primary measures are:

Strategic Policy Responses: National legislation, executive directives, strategic white papers, industrial policies, and publicly available defense procurement documents issued between 2020 and 2025 that relate to AI development, REE extraction and processing, and technology sovereignty ambitions.

Technological Investments: Quantitative assessments of public and private sector capital allocations directed toward AI R&D, REE mining and processing infrastructure, research into material substitutes, and initiatives aimed at diversifying supply chains and improving technological self-reliance.

Trade Agreements and Diplomatic Initiatives: Formalized bilateral and multilateral agreements, memoranda of understanding (MoUs), and strategic dialogues relevant to REE trade, AI technology sharing, critical minerals cooperation, and international supply chain coordination.

Collaborative Frameworks: Participation in and contributions to global and regional governance arrangements, including ethical sourcing initiatives, sustainable mining practices, technology development partnerships, and regulatory standard-setting processes.

2.3 Procedures

A qualitative, multi-method research design was employed, grounded in the traditions of comparative geopolitics, international political economy (IPE), and technology governance studies. The research process incorporated three interlinked methodological stages:

i. Content Analysis

An extensive documentary analysis was conducted, systematically reviewing primary and secondary sources related to the strategic conduct of key actors—namely China, the United States, and India—within the AI and rare earth element (REE) domains. The materials reviewed included national AI and critical minerals strategies, policy documents, legislative records, industry white papers, government press releases, and corporate disclosures from 2020 to 2025.

Peer-reviewed scholarly literature from leading journals in international relations, political science, technology policy, and resource economics was examined alongside grey literature, including think tank reports, consultancy assessments, and policy briefs. This diverse corpus enabled a comprehensive mapping of both state and non-state actor narratives and policy choices.

The content analysis employed thematic coding to identify recurring patterns, policy trajectories, technological investments, and geopolitical alignments across the three focal state actors. This analytical stage facilitated a structured comparative synthesis of how AI–REE interdependencies were framed and operationalized.

ii. Case Study Methodology

A multiple case study approach was adopted, focusing on three national actors: the People's Republic of China, the United States of America, and the Republic of India. Each case study was designed to trace how national policies on AI development and critical minerals evolved within broader geopolitical and techno-industrial contexts.

China: The analysis centered on state-led consolidation of REE supply chains, export control regimes, and AI industrial policies aligned with the Made in China 2025 blueprint.

United States: Emphasis was placed on diversification strategies, domestic mining revitalization, public-private partnerships in AI hardware ecosystems, and plurilateral diplomacy for supply chain security.

India: The case examined the evolution of India's Critical Minerals Mission, its engagements through the U.S.–India iCET framework, domestic AI capacity-building initiatives, and participation in emerging plurilateral governance coalitions.

This case study approach allowed for the identification of actor-specific causal pathways linking strategic policy decisions to broader geopolitical and technological outcomes.

iii. Comparative Cross-Case Synthesis

Following the individual case analyses, a comparative cross-case synthesis was conducted to distill patterns of convergence and divergence across the strategic approaches of the three state actors. The synthesis paid particular attention to how national AI strategies were conditioned by respective resource endowments, geopolitical imperatives, and ideological leanings—ranging from techno-nationalism to cooperative multilateralism.

This stage culminated in the formulation of a conceptual typology of strategic responses to the AI–REE nexus, allowing for generalizable insights while preserving the specificity of actor-centric trajectories.

2.4 Analytical Instruments

The study deployed a combination of analytical tools and theoretical frameworks to structure data interpretation and thematic generalization:

Geopolitical Trend Analysis: Longitudinal analysis was applied to identify shifts in policy trajectories, strategic alignments, and power asymmetries in the AI-REE domain. Both episodic developments (such as trade sanctions, resource embargoes, and major technology agreements) and systemic trends (such as the rise of techno-nationalism and plurilateral technology governance) were evaluated.

SWOT Framework: A Strengths, Weaknesses, Opportunities, and Threats (SWOT) matrix was developed for each national case, assessing their relative positions and vulnerabilities in AI innovation, REE access, supply chain resilience, and technological sovereignty.

Supply Chain Risk Assessment Models: The study incorporated industry-standard models and academic methodologies to quantify vulnerabilities in REE supply chains. Key variables included geographic concentration, geopolitical risk indices, resource substitutability, technological readiness, environmental sustainability metrics, and market elasticity. These assessments facilitated scenario planning for diversification and resilience-building.

Theoretical Integration: The empirical analysis was underpinned by insights from realist theories of international relations (emphasizing resource competition and national security imperatives), techno-nationalism (highlighting state-driven technological competitiveness), and liberal institutionalism (recognizing the role of cooperative governance mechanisms in managing shared challenges). This pluralistic theoretical lens enabled a nuanced understanding of both competitive and collaborative dynamics shaping AI-REE interdependencies.

Through this rigorous and multidimensional methodological architecture, the study provides a comprehensive, empirically grounded, and theoretically informed analysis of the coevolution of AI proliferation and REE geopolitics in the contemporary international system.

3. Results and Discussion

3.1 China's Strategic Leverage

China's ascendancy in the rare earth elements (REE) sector is neither an incidental outcome nor the byproduct of market serendipity; rather, it represents the fruition of a meticulously orchestrated, state-centric developmental strategy spanning over four decades. As early as the late 1970s and early 1980s, amid Deng Xiaoping's broader program of economic modernization, the Chinese leadership identified the strategic potential of REEs as both economic enablers and geopolitical instruments. This foresight was operationalized through a multi-pronged policy framework that integrated industrial policy, state-led investments, foreign asset acquisitions, and strategic export controls.

Beijing pursued an aggressive program of vertical integration across the REE value chain—from upstream extraction to midstream processing and downstream applications. Massive state subsidies were channeled toward domestic mining enterprises, particularly state-owned enterprises (SOEs), enabling them to outcompete global counterparts by driving down production costs and underpricing competitors. These subsidies were complemented by preferential credit lines, tax incentives, and state-sponsored R&D initiatives, aimed at enhancing domestic capabilities in REE beneficiation, separation, and metallurgical refinement technologies. In parallel, Chinese entities, often backed by the state or operating as proxies, strategically acquired foreign REE deposits and processing infrastructure, extending Beijing's reach into the global resource supply network.

Perhaps most consequential was China's implementation of restrictive export control regimes. These controls were not merely reactive trade policy instruments but deliberate tools of geo-economic statecraft. By manipulating global supply and price levels, China succeeded in undercutting foreign producers, many of whom ceased operations due to unsustainable competition—particularly in the United States and Australia during the late 1990s and early 2000s. This market domination was institutionalized by the early 2010s, with China controlling over 90% of global REE processing capacity at its peak. The state's approach aligned with the realist logic of resource securitization, wherein critical materials are not treated solely as commercial commodities but as strategic assets integral to national power projection and foreign policy leverage.

This policy architecture was vividly demonstrated in 2024, when China enacted a new round of export restrictions targeting key REEs, including dysprosium and terbium. These elements are indispensable for manufacturing high-performance permanent magnets used in aerospace, defense systems, and notably, the cooling systems and processors that support advanced AI data centers and high-performance computing (HPC) infrastructures. The official rationale presented for these restrictions emphasized environmental sustainability and conservation. However, international observers widely interpreted them as a calibrated geopolitical maneuver, coinciding with heightened trade tensions and diplomatic frictions between Beijing and multiple Western capitals (Reuters, 2024).

The ripple effects of these restrictions reverberated swiftly through the global technological and industrial landscape. Global supply chains experienced immediate constriction, leading to sharp price escalations and procurement challenges. Major stakeholders in the AI ecosystem—including semiconductor manufacturers, data center operators, renewable energy developers, and defense contractors—were compelled to expedite strategic recalibrations. This entailed efforts to diversify supply sources, invest in alternative materials research, explore recycling pathways, and engage with emerging multilateral critical minerals initiatives such as the Minerals Security Partnership (MSP) and the Quad's technology supply chain working groups.

Moreover, this episode accentuated the structural vulnerabilities inherent in the hyper-concentration of critical material supply chains. It underscored that even technologically advanced economies remain exposed to coercive leverage when they lack sufficient material sovereignty or diversified sourcing strategies. The weaponization of supply chains, once a theoretical concern in strategic policy circles, became an empirical reality affecting industries at the heart of the fourth industrial revolution.

From an analytical perspective, China's 2024 actions exemplify not only classical realist state behavior in the international system—using material resources to enhance relative power and constrain adversaries—but also a sophisticated application of geo-economic coercion and strategic market manipulation. At the same time, they have catalyzed techno-nationalist policy responses in other major powers, compelling states such as the United States and India to reassess their dependencies and to innovate toward greater self-sufficiency and resilience.

Finally, this development has invigorated nascent efforts toward liberal institutionalist solutions, including multilateral critical minerals governance frameworks. Such initiatives aim to develop shared ethical standards, improve resource transparency, promote environmental stewardship, and construct resilient supply networks that reduce the capacity of any single actor to monopolize essential materials.

Thus, China's dominance in the REE sector and its strategic behavior in 2024 serve not only as a case study of resource geopolitics in action but also as a bellwether for the interconnected future of AI proliferation, material sovereignty, and international power dynamics.

3.2 United States' Response: Diversification and Technological Innovation

The United States' strategic response to its REE dependency has been characterized by a dual-pronged policy architecture aimed at both mitigating immediate supply chain vulnerabilities and fostering long-term technological resilience. This approach reflects a synthesis of defensive realist imperatives—securing critical material access to preserve national power—and a techno-nationalist industrial strategy designed to sustain U.S. primacy in emerging technological domains, particularly Artificial Intelligence (AI).

i. Diversification and Resource Sovereignty Initiatives

In recognition of the structural risks posed by concentrated REE supply chains dominated by geopolitical rivals, the U.S. Department of Defense (DoD), in collaboration with the Departments of Energy and Commerce, has allocated over $2 billion in targeted investments since 2021. These allocations have been directed toward the revitalization of domestic mining operations, the modernization of existing REE extraction sites, and the expansion of advanced processing facilities within U.S. borders. The explicit policy objective, reaffirmed in the 2024 Defense Critical Materials Resilience Framework, is to achieve a substantial degree of REE supply chain autonomy by 2027 (USGS, 2025).

In parallel, Washington has pursued a proactive resource diplomacy agenda. Bilateral agreements have been formalized with resource-rich allies, including Australia, Canada, and Brazil. These agreements encompass not only preferential access to REE raw materials but also cooperative ventures in sustainable mining practices, environmental governance, and the establishment of redundant supply chains. Such alliances operationalize the concept of "friend-shoring"—the strategic reorientation of supply chains toward politically aligned and stable partners to reduce exposure to adversarial leverage.

These diversification efforts have been complemented by the United States' leadership in plurilateral supply chain resilience initiatives, notably the Minerals Security Partnership (MSP) and the Quad's Critical and Emerging Technology (CET) working groups. These mechanisms aim to institutionalize collective action on critical mineral sourcing, enhance market transparency, and promote shared environmental and labor standards.

ii. Technological Innovation and Material Substitution

Beyond raw material procurement, the United States has mobilized its innovation ecosystem—comprising federal research agencies, national laboratories, academic institutions, and private industry—to pioneer technological pathways that reduce or obviate REE dependencies. Leading U.S. technology firms, including NVIDIA, Intel, and Tesla, have accelerated the development of next-generation AI hardware architectures explicitly designed to minimize the incorporation of critical REEs without compromising computational performance or energy efficiency.

Simultaneously, federally funded research initiatives, coordinated by entities such as the Advanced Research Projects Agency-Energy (ARPA-E) and the National Science Foundation (NSF), have intensified efforts to identify synthetic substitutes and novel materials capable of replicating or surpassing the functional properties of rare earth-based components. Research consortia are also advancing closed-loop material cycles, with significant breakthroughs in REE recycling and reclamation technologies. These innovations aim to decouple technological progress from finite resource constraints, aligning with the principles of the circular economy and enhancing the long-term sustainability of the U.S. technology sector.

Furthermore, the U.S. has leveraged the Defense Production Act (DPA) and other strategic procurement instruments to incentivize public-private partnerships in AI hardware development. These partnerships have fostered the commercialization of advanced semiconductors, quantum computing components, and high-capacity batteries that either reduce REE intensity or employ alternative material compositions.

iii. Strategic Objectives and Geopolitical Significance

Collectively, these initiatives transcend mere risk mitigation. They are part of a broader strategy to reassert U.S. technological leadership in AI and allied fields while insulating national security and economic competitiveness from coercive material dependencies. By diversifying supply chains and fostering technological substitutability, the United States seeks to reinforce its strategic autonomy and ensure that its trajectory of innovation is not constrained by the geopolitical maneuvering of resource-dominant competitors.

From an academic standpoint, the U.S. response embodies a hybridized policy paradigm:

Realism, as expressed in efforts to secure critical material sovereignty and prevent adversarial coercion;

Techno-nationalism, in the state-led promotion of domestic technological capability; and

Elements of liberal institutionalism, as seen in efforts to multilateralize supply chain governance and promote cooperative norms among allied and partner states.

By integrating diversification with cutting-edge technological innovation, the United States is not merely reacting to existing supply chain vulnerabilities but is actively shaping the global techno-economic landscape in which AI and critical materials intersect.

3.3 India's Emergent Role: Resource Sovereignty and Technological Statecraft

India's strategic engagement with the AI–rare earth elements (REE) nexus reflects a multidimensional policy architecture, combining the assertive development of domestic resource capacity with the deliberate cultivation of technological partnerships and knowledge-sharing regimes. This approach aligns with a broader national strategy to recalibrate India's position from a peripheral participant in global value chains to a critical node in the emerging geopolitical economy of AI and critical minerals.

i. *Resource Development and Critical Mineral Sovereignty*

The launch of the Critical Minerals Mission in 2023 marked a seminal moment in India's industrial policy evolution, signaling the state's intent to mobilize latent resource endowments in pursuit of material sovereignty and strategic autonomy. The mission's objectives encompass not only the mapping, exploration, and commercial exploitation of India's extensive monazite-rich beach sand deposits—which represent one of the most significant untapped REE reserves globally—but also the advancement of indigenous processing and refining capacities.

By 2025, India had operationalized three state-of-the-art REE processing facilities, integrating both conventional extraction technologies and environmentally sustainable beneficiation methods. Collectively, these plants are projected to deliver an output covering approximately 10 percent of anticipated global REE demand (Carbon Credits, 2024). This represents a dramatic scaling of domestic capabilities and underscores India's capacity to transition from a passive commodity supplier to an active value chain participant.

The institutional architecture supporting this resource development agenda includes not only the Ministry of Mines and the Department of Science and Technology but also newly established public-private consortia that leverage the technical expertise and financial capital of both state-owned enterprises and private sector actors. Environmental sustainability and adherence to international best practices in mining governance—aligned with frameworks such as the Initiative for Responsible Mining Assurance (IRMA)—have been embedded as normative pillars of the mission, reinforcing India's commitment to ethical resource extraction.

ii. *Technological Partnerships and Collaborative Innovation*

Parallel to its resource development trajectory, India has pursued an ambitious agenda of technological capacity building, emphasizing strategic partnerships with technologically advanced allies and international research institutions. Central to this strategy is the U.S.–India Initiative on Critical and Emerging Technologies (iCET), which has emerged as a cornerstone of bilateral technological collaboration.

Under the iCET framework, India and the United States have jointly undertaken projects focused on the co-development of AI hardware solutions that reduce dependency on REEs without compromising performance benchmarks. These efforts reflect the broader techno-nationalist aspiration to indigenize critical components of the AI value chain while simultaneously leveraging collaborative innovation to accelerate development timelines.

In addition, the partnership encompasses joint research initiatives in sustainable REE mining and processing technologies, seeking to enhance the efficiency, environmental sustainability, and economic viability of domestic REE supply chains. This collaboration represents a fusion of industrial policy with science diplomacy, wherein technological knowledge transfer and cooperative R&D serve as instruments for both national development and the deepening of strategic alliances.

iii. Strategic Positioning in the Global AI Ecosystem

Through the simultaneous advancement of resource security and technological statecraft, India is positioning itself as an indispensable stakeholder within the evolving global AI ecosystem. This repositioning is not merely functional but reflects a deliberate geostrategic recalibration aimed at transitioning from a technology consumer to a co-creator and rule-shaper in international technology governance regimes.

India's integration into plurilateral frameworks—such as the Quad's Critical and Emerging Technology working groups and the Minerals Security Partnership—further amplifies its role as a bridge between advanced industrial economies and the Global South. In doing so, India contributes to the construction of diversified and resilient supply chains that dilute monopolistic concentrations of critical materials and promote inclusive, rule-based international resource governance.

iv. Analytical Perspective

From an academic lens, India's emergent strategy reflects a hybrid policy paradigm:

Realist imperatives are evident in the pursuit of material sovereignty and strategic autonomy.

Techno-nationalist frameworks manifest in the prioritization of indigenous capability development and state-supported technological advancement.

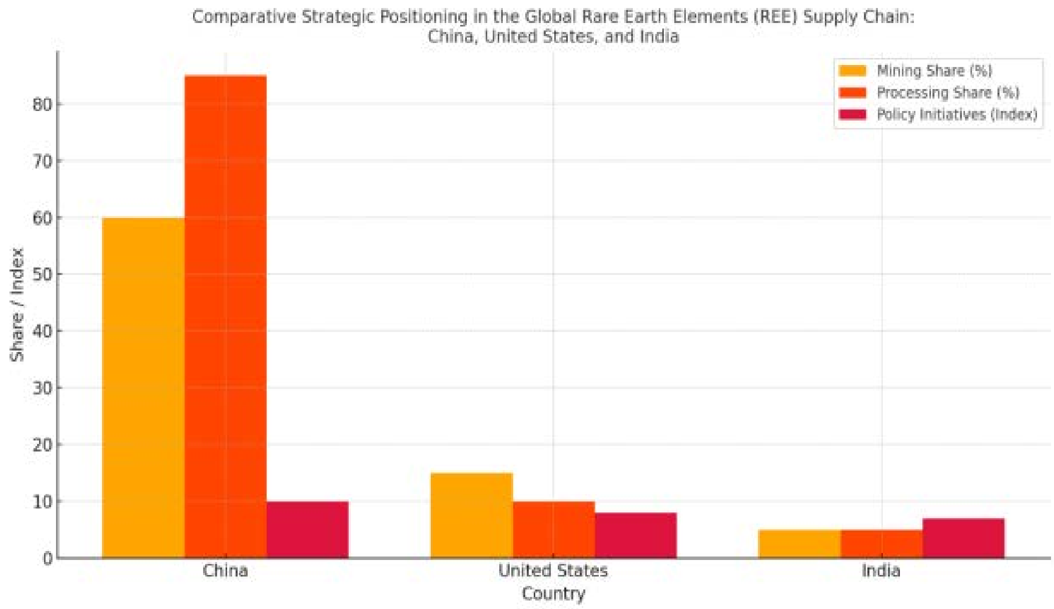
Liberal institutionalist tendencies are visible in India's commitment to international partnerships, ethical governance norms, and the multilateralization of technology and resource policy cooperation.

These policy choices align with the broader theoretical argument that middle powers—through strategic resource mobilization, diplomatic entrepreneurship, and technological collaboration—can punch above their weight in shaping the global order, particularly in domains where traditional power asymmetries are being reconfigured by technological change and material interdependencies.

Thus, India's evolving role is not merely reactive to external pressures but constitutes a proactive exercise in material diplomacy, technological statecraft, and geopolitical agency, ensuring that the nation is not only a participant but a co-architect of the emerging AI–critical materials nexus.

Comparative Strategic Positioning in the Global Rare Earth Elements (REE) Supply Chain

This visual representation compares the strategic positioning of China, the United States, and India in the global Rare Earth Elements (REE) supply chain. The comparison is based on three critical indicators: Mining Share (%), Processing Share (%), and Policy Initiatives (Index).



Key Insights:

- China leads both mining (60%) and processing (85%) activities, supported by long-term state strategies and industrial policies.
- The United States holds a modest mining share (~15%) and is still developing its processing capacities, with recent policy efforts showing gradual momentum.
- India, though currently behind in terms of share, is actively shaping its policy landscape with targeted initiatives (index value ~7) to enhance its future position.

3.4 The AI–REE–Strategy Nexus: Risks and Opportunities

The intersection of Artificial Intelligence (AI) and rare earth element (REE) geopolitics is shaping a new strategic landscape. This emerging nexus is driving shifts in national security priorities, industrial policies, and global diplomatic alignments. It presents a mix of serious challenges and new opportunities for countries and institutions worldwide.

Risks

Despite policy efforts and diversification strategies by major players, several risks continue to threaten the stability of AI–REE supply chains:

i. Ongoing Supply Chain Vulnerabilities

Even with attempts to diversify, key parts of the REE supply chain—especially refining and advanced processing—remain concentrated in a few countries, particularly China. This over-dependence creates supply bottlenecks and leaves global technology systems exposed to geopolitical tensions, trade disruptions, or sudden policy shifts.

ii. Environmental and Ethical Challenges

REE mining and processing come with heavy environmental costs—like water pollution, habitat destruction, and toxic waste. In some regions, unethical practices such as unsafe labor conditions and displacement of local communities are also widespread. These issues create reputational and regulatory risks that can delay or derail projects and invite public backlash.

iii. Rising Geopolitical Tensions

REEs are increasingly being used as tools of geopolitical power. As countries compete for control over these strategic resources, risks of diplomatic clashes and economic coercion grow. The militarization and securitization of AI technologies further amplify the potential for conflict, especially between major powers.

Opportunities

Despite the challenges, this evolving AI–REE landscape also opens up several promising avenues:

i. Strengthening Multilateral Cooperation

Groups like the Quad and the Minerals Security Partnership (MSP) are helping countries work together on resource governance. These platforms support joint investments, technology sharing, and the creation of shared standards on environmental protection and labor rights. They reduce over-reliance on any single supplier and promote fairer, more sustainable supply chains.

ii. Innovation in Recycling and Efficiency

Breakthroughs in REE recycling and substitutes are reducing dependence on mining. Techniques like bio-leaching and hydrometallurgy are making it easier to recover REEs from waste. At the same time, AI hardware is becoming more resource-efficient—delivering better performance with fewer critical materials. These developments align with circular economy principles and support long-term sustainability.

iii. India's Emerging Role

India is gaining ground as both a resource-rich country and a rising technology player. It is investing in its own REE processing capacity while forming global technology partnerships. As India strengthens its position, it may emerge as a balancing force in the current U.S.–China-dominated tech rivalry—paving the way for a more multipolar and stable global system.

Analytical Synthesis

This AI–REE landscape brings together elements of realist power politics, techno-nationalism, and liberal institutional cooperation. While competition and resource nationalism pose real threats, international cooperation and innovation offer viable solutions.

Ultimately, how countries, companies, and institutions navigate this space will determine not only their technological independence but also the broader rules and norms of global tech governance and sustainable development.

4. Conclusion

The convergence of Artificial Intelligence (AI) proliferation and the geopolitics of rare earth elements (REEs) has emerged as one of the most consequential intersections shaping 21st-century international relations, industrial strategy, and global governance. No longer a peripheral or sector-specific issue, the AI–REE nexus embodies the material, technological, and geopolitical underpinnings of the fourth industrial revolution. It has become both a battleground for strategic competition and a potential platform for multilateral cooperation, reflecting the duality inherent in contemporary global political economy.

China's entrenched dominance in REE production and processing—derived from long-term state-led industrial policy, geo-economic statecraft, and strategic control over upstream and midstream value chains—has positioned Beijing as the preeminent player in the global critical minerals landscape. This dominance has provided China with a significant instrument of structural power, enabling the selective use of supply chain coercion and market manipulation as tools of statecraft. Yet, this very asymmetry has catalyzed a strategic awakening among peer and emerging powers, generating efforts to diversify resource access, develop technological alternatives, and pursue diplomatic alignment through both bilateral partnerships and plurilateral governance frameworks.

The United States, leveraging its unparalleled financial capital, research infrastructure, and entrepreneurial ecosystem, has crafted a dual-pronged policy response. First, it has sought to minimize its resource dependencies by expanding domestic mining, securing alternative supplies through diplomatic outreach, and investing in recycling and materials science. Second, it has mobilized its national innovation system—including federal research agencies, private industry leaders, and academic institutions—to develop technological substitutes, material-efficient AI hardware, and closed-loop material cycles. These efforts reflect a policy architecture that combines realist security imperatives with techno-nationalist innovation agendas, all while selectively engaging in liberal institutionalist frameworks aimed at supply chain resilience and sustainability.

India, meanwhile, has emerged as a significant swing actor in the AI–REE geopolitical equation. Through the Critical Minerals Mission and its expanding network of bilateral and plurilateral collaborations—most notably the U.S.–India Initiative on Critical and Emerging Technologies (iCET)—India has sought to capitalize on its latent resource endowments and burgeoning technological capacity. Its approach demonstrates a hybrid model, integrating the pursuit of material sovereignty with technological statecraft and diplomatic entrepreneurship. This has allowed India not only to enhance its own resource security and technological competitiveness but also to position itself as a bridge between established technological powers and emerging economies, thereby contributing to the multipolarization of the global AI and REE order.

The evolving trilateral dynamics between China, the United States, and India underscore the critical importance of integrating national industrial policies with international collaborative mechanisms. Such frameworks are essential not only for ensuring sustainability, transparency, and ethical governance in resource extraction and technological application but also for mitigating the systemic risks inherent in concentrated supply chains and strategic rivalries. Initiatives like the Minerals Security Partnership (MSP) and the Quad's Critical and Emerging Technologies (CET) working groups exemplify early efforts to institutionalize cooperative resource governance, promote shared standards, and facilitate knowledge and technology exchange across national boundaries.

As AI continues to redefine the parameters of economic competitiveness, national security architectures, and societal transformation, the imperative for equitable and resilient access to critical materials has become an essential condition for both technological advancement and geopolitical stability. The future contours of international power distribution will likely be shaped as much by control over data, algorithms, and intellectual property as by access to the material substrates that enable technological hardware.

Looking ahead, there is an urgent need for interdisciplinary research that bridges international relations, resource economics, environmental policy, and technology studies. Scholars and policymakers alike must examine not only the roles of the principal actors but also the influence of emerging economies, non-state actors, and transnational networks. Particular attention should be paid to the potential of AI-driven resource exploration technologies, advanced recycling techniques, and blockchain-enabled supply chain transparency. These innovations offer promising avenues not only for reducing dependencies and mitigating risks but also for establishing new models of ethical resource stewardship and responsible technological governance.

In sum, the AI–REE nexus is not merely a sectoral concern or a short-term geopolitical flashpoint. It is a structural pillar of the 21st-century global order, shaping the distribution of power, the evolution of industrial and technological paradigms, and the prospects for both strategic competition and collaborative governance in the digital age. The capacity of state and non-state actors to navigate this nexus will be a defining determinant of international stability, innovation trajectories, and the ethical orientation of global technological progress.

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