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China's Global Monopoly on Rare-Earth Elements

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ABSTRACT: This article delivers a novel economic analysis of US dependence on China for rare-earth elements and sheds light on how Western nations may exploit "limit pricing" to break China's global monopoly in rare-earth element production and refinement. This analytical framework, supported by a comprehensive literature review, the application of microeconomic and industrial organization concepts, and two case-study scenarios, provides several policy recommendations to address an important foreign policy challenge for the United States.

Keywords: economics, rare-earth elements, China, limit pricing, renewable energy, defense

The rise of China as a global economic and geopolitical superpower is arguably the most important foreign policy challenge the United States has faced since the end of the Cold War. Disputes between the two countries have been geoeconomic in nature and revolve around issues such as trade imbalances, limited market access, intellectual property theft, and currency manipulation. At the same time, there is growing concern the two nations are on a path to military confrontation and may not be able to avert the *Thucydides Trap*—the tendency for conflict when an emerging power threatens to displace existing hegemonies.

Following an escalation of diplomatic tensions, former President Donald J. Trump launched a trade war in 2017 to pressure Beijing to implement significant economic reforms and tackle unfair trade practices. As a result, the two nations imposed tariffs worth hundreds of billions of dollars on one another's goods. More recently, the COVID-19 pandemic revealed the risks associated with the concentration of goods production (for example, personal protective equipment or medical supplies) in China and heightened concerns about China weaponizing supply chains for geopolitical purposes. These growing tensions also revived US concerns about its reliance on China as a primary source of rare-earth elements (REE) and rare-earth element–based products (for example, oxides and associated alloys).

Many critical military applications and industries use these elements as an input to produce advanced electronics, hybrid vehicles, wind turbines, magnets, and catalysts. More than a decade ago, pundits sounded the alarm on China strengthening its dominance in the industry via its vast reserves and

unparalleled ability to mine and refine these resources. A 2010 Government Accountability Office report presented sobering statistics about China's dominance at all levels of the REE supply chain—the country produced about 95 percent of the raw materials, 97 percent of oxides, and about 90 percent of the metal alloys.[1] From a military perspective, the report stated the US dependency on a potential adversary for critical resources could shape the outcome of a military confrontation. For example, in a large-scale, prolonged military conflict with Beijing over a dispute in the Taiwan Strait or South China Sea, the US military industrial complex could find itself struggling to secure the supplies needed to remain fully engaged in the fight.[2]

An early economic model explained how China emerged as the production market leader. Through a sequence of four supply-and-demand models, the model showed the gradual concentration of the REE supply chain in China.[3] This article expands on this model and focuses on the use of limit pricing by China to preserve its hegemony. The country's state-owned producers recurrently dialed up production and flooded global markets with cheap supplies to drive out for-profit Western competitors, preclude the buildup of strategic stockpiles, and discourage recycling programs. This article concludes recent market changes will limit Beijing's ability to manipulate prices for prolonged periods of time. Lastly, market forces alone will not address the vulnerability. Any policy solutions must involve significant and close cooperation with allies and sustained financial and political backing by the US government.

State of Rare-Earth Elements

Over the last decade China has consistently demonstrated its dominance of the REE global market. Following an incident in 2010 between a Chinese trawler and the Japanese coast guard in the contested waters of the East China Sea, Beijing stopped all shipments of these elements to Japan for nearly two months. This decision disrupted Japan's automotive industry, led to global prices spikes, and generated a global rush to secure supplies. The temporary price surge made it economically viable for previously mothballed mines to reenter the market, exposed the inability of Western nations to fill the temporary gap, and showed China was no longer a reliable long-term REE

1. Marc Humphries, "Rare Earth Elements: The Global Supply Chain," Congressional Research Service R41347, December 16, 2013.
2. Charles J. Butler, "Rare Earth Elements: China's Monopoly and Implications for U.S. National Security," *Fletcher Forum of World Affairs* 38, no. 1 (Winter 2014), https://sgp.fas.org/crs/natsec/R41347.pdf.
3. Dominik Schlinkert and Karl Geraldvan den Boogaart, "The Development of the Market for Rare Earth Elements: Insights from Economic Theory," *Resources Policy* 46 (2015): 272–80.

supplier; it also failed to persuade the US government and its allies to implement long-term solutions to this dependency.

Consequently, China continued to expand its global dominance and is now confidently wielding it as a geopolitical weapon. For example, in May 2020, President Xi Jinping made a publicized visit to a magnet facility. A few days later, an editorial by Xinhua (the government's official state-run press agency) warned that by "waging a trade war against China, the United States risks losing the supply of materials that are vital to sustaining its technological strength."[4] A month later, Beijing threatened US defense contractors with sanctions following the approval of a $620 million deal to supply missile parts to Taiwan. The PRC's Ministry of Industry and Information Technology is currently exploring future controls on REE production and exports to the United States and Europe. Chinese officials also reached out to domestic producers to assess how severely US defense contractors would be impacted by a disruption in exports in the event of a diplomatic dispute between the two countries.[5]

A targeted supply-chain disruption could cripple production of consumer products and weapons systems in the United States and its strategic partners.[6] The plausibility of this scenario represents a national security threat and intensifies the debate amongst policymakers and business communities about the United States' ability to find viable alternatives to sources of rare-earth elements. To that end, the Trump administration published Executive Order 13817, "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals," in 2017. It outlines a comprehensive set of policies and strategic goals and pushes for action in research and development, international cooperation, assessment of domestic mineral resources, streamlining federal permitting processes, and expansion of the workforce in this sector. These proposed actions highlight key economic issues that need to be addressed to mitigate the US reliance on China for rare-earth elements. In 2020, the federal government published Executive Order 13953, "Addressing the Threat to the Domestic Supply Chain from Reliance on Critical Minerals from Foreign Adversaries and Supporting the Domestic Mining and Processing Industries," which directs US federal agencies

4. Wayne M. Morrison, "Trade Dispute with China and Rare Earth Elements," Congressional Research Service in Focus, June 28, 2019.
5. Sun Yu in Beijing and Demetri Sevastopulo, "China Targets Rare Earth Export Curbs to Hobble U.S. Defense Industry" *Financial Times*, February 6, 2021.
6. Humphries, "Rare Earth Elements," 7.

to identify potential authorities and develop agency-specific plans to improve the mining and processing of rare-earth elements.[7]

The Biden administration published Executive Order 14017, "America's Supply Chains," requiring the US government to review critical supply chains and assess the the country's dependency on other nations for key resources and technologies—to include "critical minerals" and other identified strategic materials such as rare-earth elements, as determined by the Department of Defense. This policy is likely to endure future political vicissitudes given growing bipartisan calls for a gradual decoupling of the American and Chinese economies. While these policies signal a strong commitment by the US government to address this national security threat, their implementation will take time to progress and will require sustained political backing, reliable financial support by the US federal government, and the involvement of the business community.

Production, Trade, and Uses

Production and Trade

Rare-earth elements are metals desired for unique characteristics of magnetism, luminescence, and strength.[8] Contrary to what the name suggests, these elements are abundant in the earth's crust. Their rarity comes from being scattered, mixed with other minerals, and rarely found in concentrations that make extraction profitable.[9] In addition, rare-earth elements are often a by-product of other major mining activities, and reserves are geographically more concentrated than other natural resources (for example, oil or natural gas). Historically, mineral production that is highly concentrated in one or few countries is vulnerable to market manipulations and natural disasters, political changes, or environmental problems.[10] China holds 37 percent of the world's REE reserves (see table 1). Illustrative of the rapid decline of the US industry, in 2009, the

7. US Department of Energy, *Critical Minerals and Materials: U.S. Department of Energy's Strategy to Support Domestic Critical Mineral and Material Supply Chains,* FY 2021–FY 2031, January 20, 2021, www.energy.gov/sites/prod/files/2021/01/f82/DOE%20Critical%20Minerals%20and%20Materials%20Strategy_0.pdf.
8. Yufeng Chen and Biao Zheng, "What Happens after the Rare Earth Crisis: A Systematic Literature Review," *Sustainability* (2019): 11, 1288, https://www.mdpi.com/2071-1050/11/5/1288/htm.
9. Morrison, "Trade Dispute with China," 1.
10. K. J. Schulzet al., "Chapter A, "*Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply," in* Critical Mineral Resources of the United States—An Introduction, *US Geological Survey Professional Paper* 1802 (2017), A1–A14, https://pubs.usgs.gov/pp/1802/a/pp1802a.pdf.

United States accounted for 13 percent of these global reserves; a decade later, the share was reduced to 1 percent (see table 1).[11]

Table 1. Geographic distribution of REE reserves (2019)
(Source: US Geological Survey, mineral commodity summaries, 2020)

Country	Reserves	Global Share
China	44,000,000	37%
Vietnam	22,000,000	18%
Brazil	22,000,000	18%
Russia	12,000,000	10%
India	6,900,000	6%
Australia	3,300,000	3%
Greenland	1,500,000	1%
United States	1,400,000	1%
Other	6,900,000	6%
World	120,000,000	100%

China has a greater lead in output as it accounted for 68 percent of global production in 2019. This share is likely higher because illegal mining and smuggling by the Chinese are not officially tracked. According to estimates, between 50 to 60 percent of REE production in the country is considered gray/illegal.[12] The Bayan Obo mine in the Baotao province produces 50 percent of China's rare-earth elements. The Sichuan province accounts for 24 to 30 percent of China's mining, while the remaining quantities come from the southern provinces of Fujian, Guangdong, and Jiangxi.[13] While holding large reserves, Brazil and Vietnam mined miniscule quantities of rare-earth elements in 2019. Despite a recent increase in global share from 9 percent in

11. Nabeel A. Mancheri, "Chinese Monopoly in Rare Earth Elements: Supply–Demand and Industrial Applications," *China Report* 48, no. 4 (2012), 449–68.
12. Chen and Zheng, "Rare Earth Crisis," 12.
13. Frank Pothen and Kilian Fink, "A Political Economy of China's Export Restrictions on Rare Earth Elements," Centre for European Economic Research, Discussion Paper No. 15-025, 4.

2018 to 12 percent in 2019 (see figure 1), the United States remains unable to meet domestic demand as it did in the past.

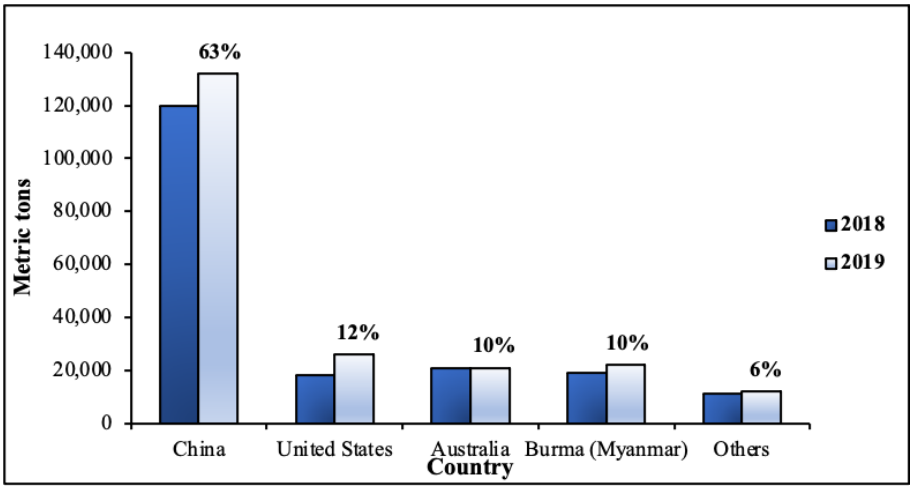

Figure 1. Geographic distribution of REE production in 2018 and 2019
(Source: US Geological Survey, 2020, mineral commodity summaries 2020)

In the past, the United States was self-reliant and the world's leading REE producer. From the mid-1960s through the 1980s, the Mountain Pass mine—located in California and owned by Molycorp Corporation—was the world's primary source of rare-earth oxides. Decades of neglect, underinvestment by the federal government and academic community, and gradual losses of knowledge and skilled labor required by this complex industry led to the decline of the industry. The downward trend culminated with the shutdown of the Mountain Pass mine in 2002 following regulatory issues and an environmental incident involving a pipeline spill carrying contaminated water. Consequently, the United States lost nearly all of its production capacity and became a net importer of these compounds and metals, with 80 percent of imports originating in China.[14]

Uses

Rare-earth elements are used in a wide range of consumer goods such as flat-screen TVs and cellphones. Other important industrial applications are catalysts for petroleum refinement and automotive catalytic converters, wind turbines, and hybrid and electric vehicles, among others. Production in the United States propelled the development of modern military technology, and the new defense applications bolstered the demand for REE inputs in turn, for jet fighter engines, Aegis-equipped destroyers and cruisers, missile guidance

14. US Geological Survey, *Mineral Commodity Summaries 2020*, US Geological Survey (website), 132, https://pubs.usgs.gov/periodicals/mcs2020/mcs2020.pdf.

systems, antimissile defenses, satellites, ammunitions, communication systems, etc.[15]An oft-cited example of the interdependency between the defense and the REE sectors is the F-35 fighter jet which requires 920 pounds (417 kg) of these materials. Also, rare-earth permanent magnets and specialized alloys are vital to many military weapons systems. Some of these critical components are exclusively built in China, which represents a threat to national security.[16] Nevertheless, the defense uses of rare-earth elements accounts for a relatively small share of US consumption—between 5 and 10 percent.[17]

As major economies transition to lower-carbon and renewable energies, analysts estimate the demand for rare-earth elements will continue to grow rapidly. Clean-energy technologies, such as hybrid electric vehicles or generators for wind turbines, could consume up to 40 percent of all REE production by 2040.[18] This figure includes China's growing downstream sector that now accounts for more than 80 percent of total global consumption.[19] The semiconductor industry—another strategically important and fast-growing sector—is also becoming a major consumer of rare-earth elements. Finally, the current lack of alternative sources plays into the growing demand for these elements. When available, substitutes tend to be less effective, and the quantity of recycled rare-earth elements remains limited (for example, materials extracted from batteries, permanent magnets, or fluorescent lamps).[20]

Chinese Dominance in the Global Market

For over five decades, China developed high-profile national programs and devoted laboratories and teams exclusively to the study of rare-earth elements. This long-term focus yielded significant results and set the conditions for the country to expand its output of rare-earth elements in the late 1970s and 1980s.[21] Chinese leaders then declared these elements "strategic" mineral resources and, with the country's high tolerance for environmental degradation and low cost of exploitation, increased production and exports throughout the 1990s. This increase caused global REE prices to plunge and resulted in many Western mining companies going bankrupt or significantly reducing

15. Morrison, "Trade Dispute with China," 2.
16. Yu and Sevastopulo, "China Targets Rare Earth," 2.
17. Alan Beattie, "Rare Earths and a Decade of Failure to Diversify," *Financial Times*, September, 25, 2020.
18. International Energy Agency, "The Role of Critical Minerals in Clean Energy Transitions," *World Energy Outlook Special Report*, May 5, 2021; and Mancheri, "Chinese Monopoly," 262.
19. Nabeel A. Mancheri et al., "Effect of Chinese Policies on Rare Earth Supply Chain Resilience," *Resources, Conservation & Recycling* 142 (2019): 101–12.
20. Butler, "Rare Earth Elements," 33; and US Geological Survey, "Mineral Commodity Summaries 2020," 200.
21. Pothen and Fink, "Political Economy," 13–14; and Cindy Hurst, *China's Rare Earth Elements Industry: What Can the West Learn?* (Washington, DC: Institute for the Analysis of Global Security, March 2010), http://www.iags.org/rareearth0310hurst.pdf%20.

operations. Beijing shifted toward developing an integrated supply chain in mining, magnets, and other value-added products and declared the development of domestic REE industries a strategic goal under the *Made in China 2025* strategy.[22] The PRC now controls most of the global value chain and accounts for nearly 90 percent of global REE refining capacity. In contrast, the United States must export its domestically mined ores to China for further processing because it lacks the refining, alloying, and fabricating capacity. This gap is not due to technological preeminence but rather Beijing's earlier tolerance for pollution and environmental degradation.[23] Production of rare-earth elements comes with an enormous environmental footprint—one ton can generate up to 60,000 cubic meters of waste gas, 200 cubic meters of acid-containing sewage water, and over one ton of radioactive waste.[24]

China recently began consolidating its control over the industry to keep prices high, reduce environmental pollution, and grant Chinese processors access to low-cost materials.[25] This consolidation is a stark reminder the Western for-profit businesses are not competing on a level playing field. Chinese authorities began setting up export quotas between 2007 and 2014. This policy, however, was not legally binding and many miners continued to exceed their output limits. Also, export restrictions were not applied to finished REE products so China continued to flood global markets with relatively cheap products. In 2014, after years of contention, the World Trade Organization declared these export quotas incompatible with trading rules. Following this decision, the PRC replaced export quotas with production quotas which have remained fairly stable since 2014. The ongoing consolidation of the industry into six state-owned enterprises is also central to efforts to tackle illegal or environmentally noncompliant mining operations.

Beijing also began focusing on ensuring the reserves remain plentiful and established commercial and national stockpiles managed by the China State Reserve Bureau. Since annual production includes stockpiling a share of REE materials, the PRC can impact global markets by manipulating its stockpile levels and influence market prices by increasing or releasing its strategic reserves for a limited period.[26] Chinese authorities also attempt to attract foreign investors to establish mining and processing facilities in the country with the lure of access to raw materials, metals, alloys, and the burgeoning Chinese market. Nonetheless, some foreign investors remain hesitant because of technology-sharing concerns.

22. Jamie Smyth, "US-China: Washington Revives Plans for Its Rare Earths Industry," *Financial Times*, Big Read, September 14, 2020.
23. Yu and Sevastopulo, "China Targets Rare Earth," 4.
24. Chen and Zheng, "What Happens," 11, 1288.
25. Mancheri et al., "Effect of Chinese Policies," 101–12.
26. Polina Klossek, Jakob Kullik, and Karl Gerald van den Boogaart, "A Systemic Approach to the Problems of the Rare Earth Market," *Resources Policy* 50 (2016): 131–40.

Overcoming China's Control over Market Prices

The surge in prices of rare-earth elements in 2010–11 revealed the vulnerability of Western nations to disruptions in the supply chain and triggered a wave of studies, government reports, and legislative efforts proposing solutions to this dependency. Popular recommendations include increasing and diversifying mining and processing activities, investing in research and development to find substitute materials, and lowering usage intensity or expanding recycling. A 2017 study by Sprecher et al. proposed a framework with mechanisms to improve resilience in supply chains.[27] The first step is the diversification of supply by promoting production in different countries or expanding recycling programs. Second, the stockpiling of materials can serve as a buffer against temporary supply disruptions. On the demand side, US manufacturers can develop technologies that reduce usage or allow for substitution. As previously discussed, the Trump administration proposed a multipronged approach to this issue through Executive Order 13817.

These efforts will face important economic challenges. First, investments in this sector are technically complex, take at least 10 years to materialize, and require a hard-to-find, skilled workforce and significant financial resources (typically over $1 billion USD). Furthermore, global pricing is far from transparent and is often affected by Chinese domestic policies. Due to the lack of information on real REE production or break-even costs in China, Western producers find it difficult to price their products competitively. This market uncertainty also exposes investors to prohibitive short-term risks and precludes new investments and the diversification of this supply chain.[28] After all, international financial markets have not forgotten recent bankruptcies of US and Australian mining operations. In this market environment, proposed solutions must first recognize the global market is not a level playing field and market-based actors are competing against a state-capitalist economy that subsidizes and controls its domestic sector.

A growing number of industry experts suggest market forces alone will not enable the development of alternative supply chains. Instead, they highlight the need for significant public funding and continued government support.[29] This is, in part, because of China's history of flooding the market with cheap rare-earth elements when it perceives credible competition from other nations. Economists call this behavior limit pricing, and it involves a monopolistic firm reducing its prices to the point where new firms will not be able to make any profit or even enter the market. While this action may lower potential short-term profits

27. Benjamin Sprecher et al., "Novel Indicators for the Quantification of Resilience in Critical Material Supply Chains, with a 2010 Rare Earth Crisis Case Study," *Environmental Science and Technology*, 51 (2017), 3860–70.

28. Klossek, Kullik, and van den Boogaart, "Systemic Approach," 131–40; and Mancheri et. al., "Effect of Chinese Policies," 101–12.

29. Smyth, "Washington Revives Plans," 6, 4.

of the monopolistic firms, it also enables them to maintain their position and long-term profitability. Limit pricing is less effective against new competitors capable of absorbing losses over time. The past financial problems and subsequent bankruptcies of Molycorp and Lynas, however, seem to indicate otherwise. Furthermore, limit pricing is more effective for industries with significant economies of scale. Entry in these types of markets is difficult and limited to a very small number of firms because of the very large required investments.[30]

The Chinese use of limit pricing impacts Western production and supply chains through three different channels: (1) impact its competitor's profitability, (2) discourage recycling, and (3) erode the need for building up strategic stockpiles.

Competitors' Profitability

China can depress global prices and render Western competitors economically unviable by increasing official production quotas or easing the crackdown on illegal mining operations. The Chinese government can also support temporary export surges by depleting its strategic REE reserves. Hence, Western governments and investors must be prepared to endure temporary losses while recognizing the use of limit pricing presents perils for China as well.[31] First, Chinese mining companies will provide resistance to lower market prices since this action will lower their short-term profits. Second, China's economic planners failed to predict the rapid surge in domestic consumption of rare-earth elements and the recent decreases in domestic production that followed the industry consolidation and tougher enforcement of environmental regulations.[32] Thus, it is unlikely China will employ price limiting for prolonged periods of time as it would divert valuable resources away from its processing industry. Lastly, surges in production and exports would accelerate the depletion of this nonrenewable resource.

Building a Recycling Program

Levels of reuse and recycling of products containing rare-earth elements remain modest worldwide, and the volume of these elements embedded in existing products or waste streams continues to be a mostly untapped source. This lack of reuse is largely explained by low market prices, logistical complexities, high set-up costs, and negative environmental impacts associated with recycling programs, mainly the use of toxic substances and the large amounts of energy required to separate rare-earth elements from recycled materials.[33]

30. Jamie Smyth, "Industry Needs a Rare Earths Supply Chain outside China" *Financial Times*, September 25, 2020.
31. Smyth, "Industry Needs Rare Earths, 6; and Beattie, "Failure to Diversify," 4.
32. Butler, "Rare Earth Elements," 30.
33. Beattie, "Failure to Diversify," 2.

A number of federally-supported, ongoing efforts in the United States seek to increase the reuse and recycling of rare-earth elements. As long as Beijing retains its pricing power, however, recycling alone will not close the wide gap between demand and supply in the near future.[34] Thus, the US government and its allies must develop long-term recycling program incentives and exploit alternative sources resilient to temporary price manipulations by China.

Building National Stockpiles

The National Defense Stockpile, established by the US Congress in 1939 (Title 50 United States Code § 98 et seq.) to decrease or avert dependency on foreign sources for supplies of strategic and critical materials in times of national emergency, was designed to store materials for a three-year war scenario and now includes 40 different commodities stockpiled nationwide, including rare-earth elements.[35] Policymakers and pundits argue end users should augment stockpile levels of raw material and REE-based critical components to cope with temporary market disruptions or supply bottlenecks—even if that augmentation means building reserves large enough to sustain production for several years. Procuring and storing large reserves can be a risky and costly decision. For example, Western governments and businesses could capitalize on a Chinese-induced market glut by building up strategic stockpiles at reduced prices. If prices remain low for longer periods of time, however, holding large stockpiles would become financially unattractive. Also, the development of new technologies could render long-term stockpiles obsolete and create significant losses for the holders.

Since military technology requires only limited quantities of rare-earth elements, diminishing supplies from China would not impact the US military complex if the US government and industry maintain reserve levels large enough to sustain manufacturing operations for several years and enough active Western mining operations remain in line. These stockpiles should be part of the US government's and manufacturers' risk management strategies and may require public subsidies and international cooperation (for example, development of a multinational consortium on REE stocking that involves multiple NATO countries). The reserves should serve as a temporary tool to absorb short-lived market disruptions until the United States can become self-reliant in mining and processing.

34. Chen and Zheng, "What Happens," 16.
35. Heidi M. Peters, "Defense Primer: Acquiring Specialty Metals, Rare Earth Magnets, and Tungsten," Congressional Research Service, In Focus, January 30, 2020; and Humphries, "Rare Earth Elements," 21.

Proposed Long-term Solutions

This section proposes a series of longer-term solutions for Western countries to counter China's dominance in the global market. These measures are well-aligned with the current market environment where Beijing is unable to use limit pricing as in the past due to its own shortages and recent strategic goals set by the US government (for example, Department of Energy).[36]

Creation of an Integrated Domestic Processing Industry

An integrated approach will enable the United States to manufacture the component parts needed by the military complex and the emerging green economy. If the United States expands its mining without developing a domestic refining and manufacturing capacity, the country will move its dependency risk along the supply chain. The following two highly probable scenarios underscore the urgent need for building domestic value-added refining, metal production, and alloying capacity in tandem with an expansion in domestic mining.

In scenario 1, China reduces its production and increases its imports. China is now a major consumer of raw rare-earth elements while its domestic production continues to decrease due to environmental and other policy constraints. The country, therefore, will have to increase its imports of REE concentrates or establish mining operations in other parts of the world, which would help them circumvent the negative environmental consequences generated by the industry. Both options will increase global competition for these raw materials and reduce availability for refiners outside China (for example, in the United States). Hence, the development of a US refining industry will inexorably depend on reliable access to raw materials mined in the United States or by its allies.

In scenario 2, China increases its production and decreases its imports. If the PRC increases production and reduces imports, Western mining operations dependent on China as an export market would be adversely impacted. Very few smelters and processors outside the country can produce REE oxides and metals. A US vertically integrated sector would guarantee a stable destination market for Western mining operations and may be the only path to attract the investor financing needed for this risky sector.[37] In order to expand its refining capacity, the United States must play catch-up and make significant investments toward rebuilding a skilled labor force and establishing a comprehensive research infrastructure. This step will require political will and significant public spending

36. US Department of Energy, *Critical Minerals and Materials*.
37. Humphries, "Rare Earth Elements."

to develop lasting partnerships between the US government, higher-education institutions, and stakeholders from the mining and financing industries. It is important to remember, Beijing channeled significant resources for decades to develop world-class scientific institutes focused exclusively on researching rare-earth elements. The United States will need to make an equal commitment to regain its first-place standing in the global marketplace.[38]

Increased Collaboration, New Procurement Strategies, and New Technologies

Certain REE materials do not exist in the United States and others are not available in economical quantities, so refining specific rare-earth elements may not be cost-effective domestically. Western nations can address these challenges via public policies, technological breakthroughs, and cooperation. The United States, the European Union, Japan, and Australia began setting up new programs involving coordination and research funding for domestic operations.

At the federal level, as proposed in Executive Order 13817, the Department of Defense can foster collaboration with friendly nations and their businesses by employing mechanisms, such as reciprocal defense procurement or security of supply arrangements, to ensure the widest supply of defense goods and services. These arrangements could expand the participation of allies and strategic partners in US defense procurement processes and guarantee acquisitions of rare-earth elements to meet pressing warfighter and industrial needs. For example, in August 2020, Ellen Lord, Department of Defense undersecretary of defense for acquisition and sustainment, announced the Pentagon was in early talks with Australia to have the country process a significant portion of rare-earth materials for the US military.[39] Also, three US and Canadian companies have joined efforts to set up a supply chain using radioactive monazite sands—a mining by-product. This collaboration will integrate the different phases of production, including mining and refinement, and will produce enough monazite to meet half of the United States' needs.[40]

End users of rare-earth elements are also key stakeholders who can shape the market through their procurement practices because lower-tier managers often make procurement decisions driven mostly by low-cost considerations, translating to purchases of cheap Chinese supplies. The United States needs a more strategic and coordinated approach to procurement that should involve

38. Pothen and Fink, "Political Economy," 13.

39. Reuters Staff, "Pentagon in Talks with Australia on Rare Earths Plant: Official," Reuters (website), August 27, 2019, https://www.reuters.com/article/us-usa-rareearths-australia/pentagon-in-talks-with-australia-on-rare-earths-plant-official-idUSKCN1VH1UY.

40. "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals," Exec. Order 13817, December 26, 2017, https://www.federalregister.gov/documents/2017/12/26/2017-27899/a-federal-strategy-to-ensure-secure-and-reliable-supplies-of-critical-minerals.

chief executives and government agencies. Finally, ongoing efforts to increase processing and manufacturing efficiency would lower material intensity and minimize waste. A new major technological breakthrough in the industry could make an impact akin to the contribution of fracking technology to US energy independence.

Conclusion

Rare-earth elements are strategic resources with multiple business and technological applications. Due to China's global dominance in the market, the US manufacturing and military sectors are vulnerable to potential Chinese political and economic aggression. Control over the supply chains should be an issue of extreme concern for Western nations because it has been for the Chinese government. While the vulnerability of the US military complex often captures headlines and the attention of policymakers, the threat to the economy is much broader and more concerning.

For example, commitments made by US and international automakers to increase the number of electric vehicles in their fleets is gaining momentum. With its vertically integrated supply chain, China now holds over 70 percent of the world's electric-vehicle battery manufacturing capacity, whereas the United States possesses less than 10 percent of the share. Moreover, Beijing has set the goal to produce 50 percent of the world's electric vehicles and 50 percent of the world's hybrid vehicles by 2025.[41] Any delays in the development of alternative REE supplies gives the PRC more time to consolidate its market position and develop new monopolies in these fast-growing economic sectors.

Following the 2010 market disruption and decades of talks, good intentions, and feeble financial commitments, Western nations have yet to change the status quo. This lack of action was partly due to Beijing's decision to flood the global market with rare-earth elements at subsidized prices, driving out for-profit competitors and dissuading new market entrants. A new window of opportunity is opening for Western businesses as demand for rare-earth elements in the PRC currently exceeds domestic supply.[42] Facing its own shortages, China will no longer be able to use limit pricing as it did in the past. This new market reality, coupled with financial backing from their respective governments, could provide Western producers enough time to emerge. Furthermore, Beijing knows

41. Smyth, "Washington Revives Plans," 7.
42. Yu and Sevastopulo, "China Targets Rare Earth," 4.

any overly aggressive move it makes will further galvanize its rivals to develop their own production and processing capacities.

Establishing a viable supply chain for rare-earth elements will take years and will require the United States to remain focused on long-term solutions. These efforts should include stockpiling and recycling, increasing domestic production and refining, and investing in joint ventures with trusted strategic partners. In order to succeed, these ventures will require significant public investments and enduring public support. Heavier involvement of Washington in this market may face domestic political headwinds and challenges in the international arena (for example, Beijing leading a complaint at the World Trade Organization). As China continues to lose market power and domestic political backing for REE independence gains momentum, the United States is well-poised to use the defense complex and create cutting-edge industries to break this long-lasting dependency.

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