GEORGETOWN UNIVERSITY

THE GEOPOLITICS, ECONOMICS, AND ENVIRONMENTAL IMPACTS OF RARE EARTH ELEMENTS

AN OPPORTUNITY FOR CHILE'S MINING SECTOR

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Dedication and Acknowledgments

This capstone project was completed as the final requirement for the Master's of Arts in Latin American Studies from the Center for Latin American Studies (CLAS) at Georgetown University's Walsh School of Foreign Service. We dedicate this work to our first- and second-year colleagues at CLAS, without whom our project would not have been possible.

We are especially grateful to Dr. John Griffiths and the AthenaLab team, and our faculty advisor, Carlos Sucre (Extractive Sector Specialist at the Inter-American Development Bank), as well as Professor Angelo Rivero Santos, for his oversight throughout our project. We extend our thanks to Professor Jenny Guardado, for her assistance with the economic aspect of our project. We would like to express our gratitude to Matt Westbrook, head of government operations for USA Rare Earths, for his pivotal advice and industry expertise.

Furthermore, we would like to offer a special thanks to our friends and family for their support throughout this process. In particular, we thank Minda and Bill Caesar as well as Charlotte Fanning for their invaluable patience and assistance throughout the course of this project.

About the Authors

Kat Caesar

Kat Caesar is an accelerated second-year student in the Latin American Studies program in Georgetown's Walsh School of Foreign Service. Through her academic journey, Kat has lived in several Latin American countries, including interning with AthenaLab in Santiago, Chile between May and August of 2022. Kat's research involves environmental security, national security, defense, and international relations with a particular interest in human rights and environmentalism. She graduated Summa Cum Laude from Wake Forest University Class of 2022 with Honors in Politics/International Affairs and Spanish, and a minor in Latin American Studies. During her time interning with AthenaLab, Kat co-authored several published articles relating to organized crime and national security, among other topics. After graduating from Georgetown, Kat hopes to pursue her passions for environmental accountability and human rights in the profession sector.

Chris Lindrud

Throughout his time at Georgetown, Chris Lindrud has centered his research around extractive industries and state-owned enterprises in Latin America. Particularly interested in international trade and development, Chris spent the summer of 2023 in Brasilia researching electric vehicle policy and potential supply chain risk exposures at INMETRO, a Brazilian regulatory agency. While at INMETRO, Chris became exposed to the role that extractive industries in Latin America will play in the green energy transition, with rare earths sourced from the region being of tantamount importance. Upon graduating from his Master's program, Chris hopes to enter the political risk consulting industry so he can continue pursuing his passion for international affairs.

Capstone Partner Organization and Deliverables

For this Capstone project, we partnered with AthenaLab, a think-tank based in Santiago, Chile, which focuses on international relations, national security, and defense. The team at AthenaLab publishes papers, articles, and columns relating to these issues (via: https://athenalab.org/). Given that our research, case studies, and conclusions were ultimately developed to provide policy recommendations for Chile's burgeoning rare earths industry, AthenaLab has generously offered to publish our work. We offer special thanks to Juan Pablo Toro, executive director of AthenaLab, for this privilege.

We submitted two deliverables to our capstone partners. First, we grant access to our powerpoint presentation as well as the recording of our presentation and photos of the same, for publication on the AthenaLab website. Second, we will produce for AthenaLab a short deliverable with a summary of our findings and recommendations. Our research will be published in both English and Spanish to increase the accessibility and reach of our work. The qualitative portion of our deliverable provides the geopolitical and legislative context framing our quantitative analysis, which analyzes the economic viability of the rare earths trade. Our deliverable represents a deep-dive into the REE industry, which weights potential benefits and detriments for Chile. As a widely growing field, we have the benefit of being at the forefront of new research. The English version of the deliverable may differ slightly from the Spanish version, which we will produce with oversight from AthenaLab.

Abbreviations

REEs: Rare Earth Elements

La: Lanthanum

Ce: Cerium

Pr: Praseodymium

Nd: Neodymium

Pm: Promethium

Sm: Samarium

Eu: Europium

Gd: Gadolinium

Tb: Terbium

Dy: Dysprosium

MOA: Memorandum of agreement

EO: Executive Order

Ho: Holmium

Er: Erbium (Er)

Tm: Thulium

Yb: Ytterbium

Lu: Lutetium

Sc: Scandium

Y: Yttrium

CDA: Community development agreements

CWA: Clean Water Act

SERNAGEOMIN: Servicio Nacional de Geología y Minería—Chile's National Geology and Mining Service

EU: European Union

WTO: World Trade Organization

CHIPS: **'**Creating Helpful Incentives to Produce Semiconductors' i.e. CHIPS and Science Act

EPA: Environmental Protection Agency

TENORM: Technologically Enhanced Naturally Occurring Radioactive Materials

Key Terms

Lanthanide: Any of the series of 15 elements on the periodic table ranging from lanthanum to luteum.

Rare earth elements: A category of 15 lanthanide elements, plus scandium and yttrium, with unique but shared chemical properties essential to producing technologies like electric vehicle batteries, catalysts, computers, magnets, and cell phones.

Light rare earth elements: This sub-category of elements includes lanthanum, cerium, praseodymium, neodymium, promethium and samarium. They are generally more commonly found on earth, and therefore, typically less valuable than heavy rare earths.

Heavy rare earth elements: Europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, and ytterbium are all considered part of this category because their comparatively larger atomic weight makes them "heavy" compared to "light" rare earths. Due to their similar characteristics, yttrium and lutetium are also sometimes included within this category as well.

Critical minerals: Refers to a class of minerals declared geopolitically crucial to one or more countries.

Ferromagnetic: A property of certain metals which allows two electrically uncharged materials to attract others.

Paramagnetic: A quality of certain metals which characterizes a very weak magnetic attraction.

Pyrophoric: A quality of certain metals which causes them to spontaneously ignite when exposed to air.

Executive Summary

Rare earth elements (REEs), also known as rare earth minerals or rare earth metals, represent a grouping of seventeen unique elements on the periodic table. Given their industrial and technological applications, several countries and coalitions, including the United States, Japan, and the EU, have declared these minerals to be 'critical' — defined as a "non-fuel mineral or mineral material essential to the economic or national security of the U.S. and which has a supply chain vulnerable to disruption"[1]. Amongst their most important applications, REEs are notable for their uses in both the defense and the green technology sector. As such, governments around the world want to increase domestic production of these REEs or find stable sourcing partners. In particular, the United States under the Biden administration along with other countries want to move the market away from China — which currently monopolizes some 80% of production and processing. The monopolization of the industry by China means that crucial minerals could be cut off from the rest of the world to pressure compliance — as seen in the case of the China-Japan dispute in 2010.

On the global macro-level, both geopolitical and economic factors contribute to the need to expand the REE industry. The growing demand for REEs, and their increasing importance for civil, military, and nuclear technologies necessitate a corresponding growth of supply. Foreign investment and domestic firms interact with local laws and regulations, with the REE sector being a particularly attractive new industry given its strategic and economic implications. However, while the mining industry plays a large role in economic prosperity, there have also been concerns about the industry's negative impact — for example, on the environment and on local communities. As such, the extractive industry in China faces severe scrutiny for their environmentally degrading and otherwise harmful extraction and processing methods. While potential benefits, such as economic growth and local job opportunities encourage countries to allow foreign investment, major concerns like environmental degradation, human rights abuses, corruption, and regulatory hurdles often arise as a result of the complex and poorly understood nature of the industry.

Amongst calls for increasing REE production, this capstone explores the possibility of expanding the rare earth elements industry into Chile—a country which, although small, has the

[1]USGS. 2022. "U.S. Geological Survey Releases 2022 List of Critical Minerals | U.S. Geological Survey." 2022. https://www.usgs.gov/news/national-news-release/us-geological-survey-releases-2022-list-critical-minerals.

deposits and the strong mining economy to potentially create a booming REE market. This capstone project analyzes the existent REE industries in the United States and Brazil, two of the region's strongest economies and major players in the global REE market. Through these analyses, we weigh the costs and benefits of increasing REE mining through two lenses: a geopolitical macro-level lens of diversifying the source of REEs from China and a micro-level assessment of the environmental and economic strengths and critiques in the United States and Brazil. Companies in the United States have already begun to corner the domestic market, investing in their own technological capacity to produce and refine these critical minerals. We found that the United States REE industry is particularly strong in its evolving legislation and rigorous permitting process, with active federal support including grant/loan money/tax incentives. However, the historic lack of sensitivity for local community concerns and bureaucratic obstacles could make producing and refining REE in the USA particularly difficult. In Brazil, conversely, active government support for private sector actors in the REE sector has caused an environment of state-sponsored favoritism. Certain large-scale mining operations reap the benefits of government investment and favorable legislation which undermines the efficacy of Brazil's regulatory accountability mechanisms and the emergence of new actors in the rare earths mining sector.

We then analyze Chile as our focus case study. As the country's REE industry is only just beginning to develop, we use Chile's major mining industries of copper and lithium as a proxy to identify strengths and areas of improvement of the mining sector as a whole. We found that Chile would be a good fit for the REE industry based on its quality and quantity of reserves; existing mining infrastructure; and strong legal framework which could be expanded to encompass REE-specific legislation. However, we identified the following areas of improvement: a lack of public participation and Indigenous rights in the mining sector; issues surrounding energy, water, and environmental protections; and a lack of REE-specific industry background.

Using the two lessons learned from our Brazil and Chile case studies, we assess the potential for expansion of REE growth into Chile and offer policy recommendations to maximize the economic, geopolitical, and social benefits associated with this burgeoning industry. Our recommendations aim to balance the interests of various stakeholders so that the potential negative externalities associated with the REE industry are limited to maximize the sector's overall net benefits. As Chile considers foreign countries' calls for an increase in mining of

REEs, the government will need to create new regulations with concrete goals and evaluate the costs and benefits of entering the REE industry. In particular, we found that the relationship between the private and public sectors ultimately determines the specific nature and overall viability of a country's REE sector, requiring strong cooperation between these two actors. We also identified the need for creating and enforcing REE-specific regulations, which prioritize environmental protections and offer voices to community members. Finally, further research into the REE industry is necessary to create more sustainable methods of extraction and processing for these critical minerals.

Through our geopolitical, economic, and case study analyses, we determined the necessity of three 'licenses to operate'. First, the economic license to operate requires that the REE industry provide economic benefits to both companies and governments. Second, the social license to operate requires that stakeholders work alongside local governments and communities to develop a mutually-vested interest in the success of a REE operation. Finally, the political license to operate requires that both local and geopolitical risks are considered when making the decision to enter the REE industry under a policy framework balancing private sector profitability and public sector accountability.

Part I: Introduction

Rare earth elements (REEs) are crucial in the twenty-first century; their unique properties make them indispensable to producing technologies we use every day — from clean energy or green technologies to high-level military applications to electronics, and are largely responsible for the smaller, lighter weight handheld phones and laptops. These essential uses led to a rising geopolitical salience for REEs after a crisis in 2010 when China, the world's largest exporter, blocked Japan from importing REEs in retaliation for a dispute over fishing zones. As such, demand for REEs skyrocketed in the 2010s, and mineral commodity pricing for REEs remains extremely high. The increase in demand, and desire by much of the world for more stable producers, an emerging gap in the REE market presents an opportunity to exporting countries.

REEs represent seventeen unique elements on the periodic table which are essential base minerals with applications across various industries such as the defense, industrial, and green technology sectors around the world. The term rare earths, however, is a misnomer; these minerals are neither "rare" nor "earths". Rare earths are rather plentiful, but typically found in relatively small concentrations which make large-scale mining operations not economically viable. Cerium, for example, is three times more abundant than lead[2] in the Earth's crust. Furthermore, REEs are often found alongside other mineral deposits like iron or copper. However, REEs are often found in comparatively small quantities within these other deposits, making it economically unfeasible to develop an entirely separate refining process to utilize these proportionally smaller REE resources.

Their uses include batteries, such as those in smartphones, lightweight computer hard drives, audio speakers, and on the other end of the spectrum, military craft like fighter jets and powerful magnets used in propulsion motors. REEs are also crucial elements used in green technologies, including electric car batteries, solar panels, and batteries to store energy from alternative power sources. Other elements, such as lithium or cobalt, are often grouped with rare earths because they are similarly used in electronics and batteries. However, lithium and other non-REEs lack the unique chemical properties which make rare earths particularly valuable. A full list of REEs uses may be found in Annex 1. For the purposes of this capstone, we will also

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[2]Lee, Jordy. 2021. "Rare Earths Explained." Milken Institute Review. July 26, 2021. https://www.milkenreview.org/articles/rare-earths-explained.

be studying niobium, a mineral often included in this category by policy makers but not chemically recognized as an REE on the periodic table. Given that niobium is often used in applications alongside rare earths, and is frequently categorized as such within the scope of REE policy decisions, unlike lithium which is typically legislated separately as an individual mineral, incorporating niobium into our capstone provides a holistic and comprehensive analysis of REE policy.

The relative abundance of REEs in the Earth's crust combined with increasing global demand has made leveraging these underexploited mineral reserves a particularly attractive economic endeavor. Having become economically viable only within the past few decades, the scale of the rare earth metal industry is small yet rapidly growing when compared to other traditional mining sectors. According to the United States Geological Survey, there are an estimated 120 million tons of rare-earth reserves throughout the world. Among the countries with the largest reserves are China (44 million tons), Vietnam (22 million), along with Brazil and Madagascar (21 million each). However, the annual production of these latter three countries together did not exceed 4,100 tons in 2021—meaning that the market continues to depend almost entirely on China[3].

Given the increasing importance of these sectors to the global economy, a growing number of countries and researchers alike have acknowledged the need to increase the rate and scale of mining for REEs to satisfy global demand. Furthermore, diversifying supply chains of REE has become a central policy goal given that the industry is concentrated in a select few countries, giving them significant leverage over the base minerals essential to technology production and the green energy transition. Specifically, although many countries hold rare earths reserves, China in particular has developed a near-monopoly over the global rare earths trade. While China currently holds 35% of global rare earths reserves, the country is responsible for over 80% of REE exports, becoming a strategic supply chain vulnerability as China has developed a particularly salient yet niche point of leverage over rival countries[4]. As countries seek to economically decouple from China, rare earths have become an increasingly coveted natural resource.

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[3]Encyclopedia Britannica. n.d. "Britannica Money." Accessed May 7, 2023. https://www.britannica.com/money/rare-earth-metals.
[4]Earth.Org. 2020. "How Rare-Earth Mining Has Devastated China's Environment." Earth.Org. July 14, 2020. https://earth.org/rare-earth-mining-has-devastated-chinas-environment/.

However, there are few alternate sourcing partners; despite their abundant dispersion on our planet, rare earths are only concentrated in economically viable quantities in a limited number of countries. Furthermore, the extractive process requires significant investment in terms of human and financial capital to develop the infrastructure and technical capacity to mine and process rare earths. However, as the political concerns surrounding the reliability of rare earths supply chains becomes more salient as relations between China and its rivals deteriorates, the increasing demand for these minerals and global interest in diversifying REE sourcing partners has translated into new opportunities for non-aligned countries to strategically leverage their own underexploited REE reserves. These opportunities are limited—few countries have viable quantities of REEs for extraction, and even fewer have the pre-existing mining infrastructure, technical expertise, and regulatory capacity to laterally expand into this sector in such a way that provides a net economic benefit while mitigating industry's potential negative externalities. It is within this context that Nayar (2019) raises a valuable question: "If REE mining produces such substantial environmental impacts that it contributes to the climate problem more than it mitigates,"[5] does this defeat the purpose of using REEs as a source of green technology?

Given the unique nature of the REE mining industry and the country's strong background in operating technically sophisticated large-scale mining operations, we identified Chile as an ideal contender to become an alternate sourcing destination in the REE trade. Chile, with its already robust mining sector and recently discovered rare earth deposits, could enter this growing market in a way that is both politically feasible and economically viable. On one hand, the consistently rising prices and relatively stable growth forecast for these minerals could provide a massive economic opportunity for emerging exporter countries. On the other hand, however, Chile's mining industry and regulatory framework must correspondingly expand to facilitate profitability and global competitiveness while simultaneously ensuring the industry's negative externalities remain sufficiently managed so that issues surrounding potential environmental degradation and social concerns do not undermine the overall viability of the country's burgeoning REE industry.

Through this study, we analyzed the existent mining industries of the two largest economies in the Americas, the United States and Brazil, and their position within the global

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[5]Nayar, Jaya. 2021. "Not So 'Green' Technology: The Complicated Legacy of Rare Earth Mining." Harvard International Review. August 12, 2021. https://hir.harvard.edu/not-so-green-technology-the-complicated-legacy-of-rare-earth-mining/.

REE trade to make policy recommendations for Chile. As important historic actors in the global rare earths sector, the USA and Brazil are similarly expanding their own REE production capacity, albeit inspired by divergent economic and political motives, in response to the increasing fragility of global supply chains. Because of this, using lessons learned from our Brazil and USA case studies, we identified the conditions necessary for Chile to maximize the potential of its incipient REE industry to further center itself as a strategic trade partner within global mineral supply chains. Through our research, we answer three questions about the REE industry:

1. What are the geopolitical conditions framing the global rare earths trade?
2. How can these geopolitical shifts and global interest in diversifying global supply chains inform Chile's decision to develop its own domestic REE industry, using studies of other countries?
3. How can Chile maximize the potential of its incipient REE industry while simultaneously managing inevitable negative externalities to balance economic, social, and political interests?

This capstone identifies the strengths and weaknesses of the mining sectors in the United States, Brazil, and Chile. Based on our findings, we determined the following points as the most salient factors responsible for maximizing the potential of Chile's REE industry:

1. **The relationship between the private and public sectors**

   (The political license to operate)

2. **Implications for social and environmental stakeholders**

   (The social license to operate)

3. **Profitability and economic potential**

   (The economic license to operate)

The aforementioned factors are all interconnected; as a result, lacking one "license to operate" undermines the overall potential of the entire operation. The relationship between the public and private sector determines the nature of government support for mining activities and the efficacy of regulatory accountability measures impacting social and environmental stakeholders. The profitability of the activity impacts the relationship between the public and private sector because mining operations generate royalties for the government, encouraging the intensification of extractive activities often at the expense of local and environmental stakeholders. Finally, if these vested interests are not sufficiently balanced, local and environmental stakeholders threatened by the mining operation can protest or file lawsuits, potentially halting the mining operation altogether. However, negative externalities are sufficiently mitigated, local communities can enjoy the economic benefits such as the jobs and parallel industries which correspondingly emerge as a result of a successful mining operation. As a result, an extractive operation must conduct itself in such a way that all three points of potential contention develop a convergent, mutually-vested interest in the success of the mine by ensuring the gravity of the operation's negative externalities do not eclipse its net benefits.

To answer our research questions, we incorporate our discoveries into a multi-part analysis. Part I includes the introduction, the methodology, and the literature review to initiate the argument. Part II explores the history and the contemporary geopolitical context framing the global REE trade, with emphasis on China's role and market domination, critical mineral policy, and the major industries for importers of REEs: defense, green technology, and industrial/technological applications. Part II analyzes the potential benefits and detriments of expanding the REE industry, including economic trends of REEs, their price value increase on the global market, along with environmental degradation and radioactivity concerns. Part IV breaks down the major mining industries of our three focus countries: The United States, Brazil, and Chile. Finally, after identifying the strengths and weaknesses of each of these factors, Part V provides a strategic analysis, using lessons from our case studies, to ultimately make policy recommendations for Chile and suggest areas of future research. Part VI contains our conclusions, contributions, and reflections on the project. Finally, our Annex offers a comprehensive "beginner's guide" to rare earths, including basic breakdowns of each mineral and their most common uses.

Methodology

The methodology of this project was designed to illustrate the macro- and micro- political and economic potential of developing a country's REE mining sector. Given the complexity and interdisciplinary nature of our research, the data in this capstone comes from several sources. We complement analyses of statistical information and case studies with a content analysis of extant literature as well as government websites, publications, and state institutions. There are a plethora of sources currently publishing data on rare earths, but we focused on only official collected data from our chosen countries. Furthermore, because chemists have a more narrow definition of REEs than policy makers, who categorize minerals like niobium within the scope of REE legislation because of their convergent strategic implications, our analysis of the global industry uses the wider definition of the term used by government agencies. As such, our major data sources were the US Geological Survey and the national statistical agencies of our countries of interest: the *Institución Nacional de Estadísticas (INE)* in Chile, the *Instituto Brasileiro de Geografia e Estatística* (IGBE) in Brazil, and the US Geological Survey (USGS) in the United States.

The project addresses geopolitical and economic factors which could influence the expansion of REEs. On a macro level, geopolitical and economic factors affect both the rising demand and need to diversify the supply of REEs. As part of our macro-level analysis, we engaged with five experts in the field in a conversational capacity to narrow down our focus and data sources. We documented mentions of REEs in official government sources in our chosen countries: the United States, Brazil, and Chile. Furthermore, we analyzed how each of these countries fit into the global REE market to analyze market trends and import values. As such, we examined the historical development of policy and current legislation impacting the REE industries in the aforementioned countries, paying particular attention to how domestic legislation impacts geopolitics and divergent national mineral security strategies.

We followed this section with a quantitative analysis of the economics of REEs, by creating correlational models between unit price and time, in order to compare the value of REEs with Chile's other major mining industries of lithium and copper. Our correlational analyses measure increases in price from 1960-2019 and 1990-2019, measuring both slope and confidence to assess volatility and prices increases. We also analyze the market price increase from

2018-2022, increases in the GDP growth of Chile, and world production of REEs to argue the relevance of this sector.

Using this information to frame our analysis, we developed two REE- specific case studies, in the United States and Brazil respectively, to identify strengths and weaknesses of the mining industries in two regional economic powerhouses. We particularly measure political, economic, and social issues relating to the REE sector. Through our assessment of these industries, we offered recommendations to Chile based on our findings, tailored to the gaps we found through our principal analysis of their current REE and mining industries. Based on our findings, we identified the political, social, and economic licenses to operate as crucial factors influencing the success of a country's REE industry.

We furthermore developed a qualitative analysis to assess the viability of expanding the rare earths industry in Chile. First, we identified the key uses and importance of REEs. Then, we argue the increasing geopolitical relevance of the REE industry, and position Chile as a potential market to expand REE extraction and processing. Our analyses follow by first establishing the economic benefits of expanding the REE market, including a side-by-side comparison of the pricing of major Chilean mineral exports copper and lithium markets, compared with REE pricing and projections to assess market benefits of the projected stability of the REE market. We use copper and lithium mining as proxies to analyze potential strengths and areas for improvement for the Chilean mining industry.

By comparing the existing dominant industries with our focus industry, we evaluated the costs and benefits of expanding REE extractives into Chile. Finally, we offered country and context-specific recommendations to policymakers.

Literature Review

This literature review is divided into 4 sections, providing a sample of the extensive published research regarding mining practices, environmental implications, along with the local and geopolitical context of the global REE industry. Given the growing demand for REEs and advanced technology within the rising geopolitical tensions between China and the West, public and private sector actors from various countries are being forced to adapt their domestic policies and operations to balance local and international concerns.

By looking at case studies in both Brazil and the United States, we provide recommendations which support the growth of the rare earths industry in Chile. This analysis identifies and fills gaps in extant literature surrounding this industry as it relates to human rights, economic, and political implications of the growing rare earth metal mining sector in the Southern Cone, using the United States and Brazil as comparative case studies given the prevalence and maturity of the industry in both countries.

Divergent Mining Practices

Mining practices vary by nation and stringency of regulatory standards. China, for example, has been able to develop a competitive advantage in the REE mining and refining industry because of its comparatively loose labor and industrial standards. As a result, mining practices are not universal; rather, they are informed by the political, social, and economic context of each nation. Dong et al. (2021) published a report on the extraction and separation of individual rare earth elements to overcome limitations of pre-existing separation methods. The authors used an REE-selective lanmodulin protein to enable REE purification and separation and found that lanmodulin is almost a billion times better at binding to rare earth elements compared with other metals. Although this technology is still in the development stage and being refined before widely applied, the possibility of an ecologically-friendly alternative to other methods of separation bode well for the viability of the industry.

Within a single nation, both domestic and foreign firms operate parallel in the REE mining sectors. However, contrary to commonly held Western perceptions of Chinese business practices, foreign REE mining companies, regardless if they are Chinese or Western, have proven to consistently violate labor and environmental regulations in Latin America. Irwin and Gallagher (2013) investigated Chinese mining practices in Latin America, especially noting the egregious violations of labor and environmental standards in the case of Peru. The authors used both personal interviews and data analyses to determine the labor and environmental performance of foreign investment. Through their research, Irwin and Gallagher found that the Shougang Hierro Peru Chinese company did have a poor labor and environmental record in Peru, but the United States and Peru-based companies reported performing as bad if not worse, and that issues are endemic to the sector (Irwin and Gallagher, 2013).

Not only are the mining firms themselves subject to constant regulatory scrutiny, but the process to secure operation permits and export REEs is rife with problematic practices. Goudsmit (2019) writes that the opaque nature of the rare earths industry translates into a production ecosystem conducive to similarly untransparent business and regulatory practices. Within this context, corruption is rampant. According to Goudsmit, actors involved in the rare earths industry in both the public and private sector have been implicated in uncompetitive business processes; this is not only costly, but also reinforced rent seeking relationships between actors in the public and private sectors, which translates into an otherwise avoidable structural inefficiency. Although the specific extractive strategy a company uses to mine REEs depends on the nation's policy ecosystem, the overall lack of industry transparency undermines effective regulatory accountability.

Environmental Implications

Divergent global mining practices have a corresponding environmental impact, both of which are informed by domestic and international policy conditions. The environmental impact of the REE mining sector has a direct relationship with the ability of a company to secure the social license to operate at both the local and national level. Bundschuh, Litter, Parvez, and Román-Ross (2012) noted that access to water is critical to the mining process, but the corresponding chemicals needed to extract and purify the minerals leach into soil and poison the water table below ground. This is the same water resource used for human consumption (both by miners and the local community). As a result, the water table and the soil surrounding the mining operation remains polluted long after mining activity has ended, preventing agricultural or other potentially economically viable activities from taking place in the former mining area indefinitely. Because rare earth metals are often found alongside other more common minerals, such as iron or copper, albeit in smaller quantities, environmentally destructive methods associated with extracting one mineral type often exist in tandem with the other, potentially compounding the impact in the surrounding area.

Negotiating divergent vested interests at the local and national level often forms the basis of domestic and international policy surrounding the REE industry. The United Nations Environment Programme (1999) studied the effectiveness of Chile's mining sector. The country has been involved in tariff reductions, and changes in regulatory framework concerning the foreign direct investment regime. This report analyzes the environmental effects of the mining industry, including air and water quality and damage to biodiversity. Chile's mining industry is crucial to the country's economy; the authors note the fiscal benefits and foreign investment attracted by the industry. The review found that environmental management was a priority at some mines, like the Escondida Mine—at which the environmental standards were efficient.

Water rights often sit at the center of land-use and extractive industry policy, often becoming the central point of contention between local communities and mining firms. In the Atacama, the driest desert in the world and an important mining region, water is a commodity that is as important as it is scarce. Edwards, Cristi, and Gonzalo (2018) noted that Chile, a nation especially reliant on mining exports from its arid north, is particularly vulnerable to water irregularities in this economically critical but ecologically fragile region. Additionally, the Atacama is home to a significant concentration of Chile's Indigenous population, a factor further complicating issues surrounding land and water rights. Mining for rare earths in the Atacama comes with significant social and political strings attached, complications which may undermine the overall economic viability of this potentially lucrative natural resource.

The increase in mining of REEs has been proven geologically viable, with the Southern Cone being a particularly promising investment destination to service global green technology supply chains. Zhang et al. (2022) notes the importance of REEs to create new climate-friendly infrastructure such as wind and solar farms, hydroelectric generating stations, and nuclear power plants. This study emphasizes the importance of materials needed for low-carbon electricity generation, especially as international climate goals necessitate a reduction in fossil fuel electricity generation. The investigators found that between 2020 and 2050, mineral demands are likely to increase but will not exceed geological reserves — and furthermore, that annual production of neodymium (Nd), dysprosium (Dy), and tellurium (Te) may need to grow considerably. Notably, the authors found that mineral demands will not cumulatively exceed geological reserves — meaning that mining REEs would significantly positively impact fossil fuel alternatives and are viable for increased use.

As an extractive sector that inherently degrades the local environment to varying degrees, but is critical to the global green energy transition, the REE industry is often portrayed as a necessary evil for the greater good of humanity. Caitlyn Purdy and Rodrigo Castillo (2022) write on the importance of critical minerals, also called future-facing commodities in the global energy transition—particularly as rare earth minerals are considered to be a more sustainable development opportunity. They identify two possible issues with the mining of these minerals: first, conflicts over natural resource governance and opposition to mining based on "environmental impacts, insufficient consultation with affected communities, and inequitable distribution of socioeconomic benefits". Secondarily, they identify uncertainty about future demand for rare earth minerals. The researchers ultimately recommended that most governments in the region need to produce concrete steps to regulating mining, particularly of rare earth minerals, in sustainable and protective ways: for example, concrete regulation on water use. Because of this, for the REE industry to truly realize its full potential, a comprehensive regulatory framework must also be complemented by effective accountability mechanisms to ensure the ecological impact of the global green technology industry is not undermined by intense localized pollution.

Geopolitical Context

Given the global nature of the industry, the REE mining sector is particularly vulnerable to geopolitical fluctuations. Furthermore, although REE production is increasing elsewhere, namely in the Southern Cone, China still is the largest actor in the global REE trade. De Onis (2014) investigated whether Chinese investment has eclipsed US investment in Latin America. He notes that not only Chinese and North American investment has increased, but also Anglo-Dutch and French. De Onis discusses Chinese investment as "soft power," becoming a geopolitical bond between Latin America and China. Overall, de Onis found that both China and the United States are impactful for the mining sector and noted the possibility of continued competition for resources in the region (2014).

Western countries are seeking alternative REE sourcing partners, undermining Chinese leverage in this sector through supply chains diversification strategies oriented towards the Southern Cone. According to Douglas and Yates (2020), since China has eclipsed Russia as the United States's primary rival in the international area, this "great power" competition has manifested both politically and economically in the Southern Cone of South America.

Nonetheless, the different foreign policy agendas of the three countries in the rare earths sector, informed by their relative standing in respect to each other, will prove to be a critical new frontier for this multipolar interstate rivalry. Furthermore, as China and the United States are increasingly decoupling economically, access to limited rare earth metal reserves in the Southern Cone will become increasingly contentious. Although benefiting from both US and Chinese investment at the moment, eventually Chile and Brazil may have to pick sides.

Foreign policy efforts towards securing critical mineral resources often include niobium and tantalum within the scope of REE policy, despite not being officially categorized as such on the periodic table, because niobium and tantalum are often used in similar green technology and military applications as REEs. David S. Abraham outlines the technical and geopolitical implications of the global rare earth minerals industry in his book *The Elements of Power* (2017). Specifically, Abraham explains how globalized supply chains relying on the rare earth minerals face a concerning geopolitical choke point due to their over reliance on Chinese mining and refining of these critical minerals. As a result, even niobium mined in Brazil is not completely insulated from this strategic supply chain weakness, because for it to enter Western markets, it often goes through Chinese refineries first. Furthermore, a lack of transparency in the global rare earths trade, which is largely controlled by a single concentrated group of middlemen who closely guard industry data surrounding mineral prices and nation-of-origin information, makes evaluating the sourcing and market activity of the rare earths trade uniquely difficult compared to other commodities. As a result, state and non-state actors alike play a role in maintaining the opacity of the global rare earth mineral trade, putting supply chains further at risk of geopolitical instability.

Despite their global abundance, mining and refining operations are largely concentrated in a select few countries, opening space for state and non-state actors to politically influence the market for these minerals in such a way that undermines traditional notions of free trade. Kenith Veronese explains in his book *Rare: the High-Stakes Race to Satisfy our Need for the Scarcest Metals on Earth* (2015) that traditional conceptions of the law of supply and demand in economics are complicated by the geopolitical and technological dimensions of the global rare earths industry. Veronese details the technical applications of various rare earth minerals and their unique sensitivities to geopolitical volatility as a result. Both the rate of technological advancement, in addition to the increasing scale demand for new technology, is putting upward pressure on the demand for rare earth minerals; however, there is a disconnect between this growing demand and the costly rare earth mineral extraction and refining process.

The limited concentration of the global REE industry is becoming an increasingly contentious strategic vulnerability as both the scale of the industry and the demand of REE is growing without the entrance of sufficient new market actors to diversify supply chains. Guillaume Pitron writes in his book *The Rare Metal War: the Dark Side of Clean Energy and Digital Technologies* (2020) about how the strategic implications of these minerals influence trade policy and technological advancement. Pitron cites China's control over the global rare earths industry as the nation's "foreign policy weapon of choice", by purposefully suppressing the price of the their rare earth mineral exports to gain a competitive advantage over other potential global exporters, causing the industry to become concentrated in China, and therefore becoming a source of political and economic leverage over other countries. The author then explains how other countries have placed export control on these critical minerals, such as Argentina, albeit to lower degrees of success, because they cannot export rare earths at the scale nor the price that China does. Specifically, the author argues that these policies have undermined the viability of rare earth minerals produced not just in the USA but also in Europe, causing the region to rely on minerals sourced from China for its own military and green technology sectors.

Countries similarly threatened by this strategic concentration of the rare earths industry, however, despite their shared interest in divesting from China, are struggling to develop coherent policies, with the United States being particularly at risk, because domestic interest is not translating into sufficient political action. In *China and the Geopolitics of Rare Earths* by Sophia Kalantzakos (2017), the author outlines how the trade imbalance between China and the United States, among other countries, in the rare earths sector is becoming a growing strategic concern, forcing Western countries to craft policies to either develop their own domestic industries or source minerals elsewhere. Kalantzakos compares this trade imbalance to how OPEC can influence oil pricing, using the cartel to their geopolitical advantage. As a result, the shifting international geopolitical context under which the global REE industry operates is proving to be a source of both opportunity and frustration for state and non-state actors alike.

Local Political Context

Julie Michelle Klinger in *Rare Earth Frontieres: from Terrestrial Subsoils to Lunar Landscapes* (2017) describes how the social, political, and economic contexts have influenced the development of the rare earth mineral industries in various countries. Specifically, Klinger notes how mining policy in Brazil has historically been a vector for the nation to assert its territorial claims in isolated regions in the country's interior and remote border areas throughout its history. However, Brazil's history of statist developmentalism has caused certain large mining firms to gain a privileged position within the nation's policy framework at the expense of historically underrepresented groups such as Indigenous people. As a result, rare earths mining policy has become an extension of tension surrounding the concept of "true" citizenship, with sectors of Brazilian society benefiting from their privileged relationship with the state insofar as their economic interest aligns with the political goals of the state.

Blaza, Diaz, Gomez-Parra, and Manzano (2022) outline how mining firms obtain the "social license" to operate in Latin America. Given the often tense relationship between firms in the extractive sector and the local community surrounding the operation, obtaining a "social license" to operate is of tantamount importance to the mining industry. Failure to do so undermines the overall viability of the operation, forcing extractive firms to close an otherwise profitable business if the local community feels threatened by its existence. Firms can avoid this by engaging with the local community in such a way that demonstrates both the company and the local stakeholders have a vested interest in the success of the operation, doing so by providing tangible economic benefits to the local area while ensuring strict regulatory compliance to build mutual trust. Historically, extractive industries, especially when run by foreign firms, have often been met with suspicion and resentment in Latin America, so taking measures to build public confidence and local support is critical to the success of any new REE mining operation.

In his book *Gold, Oil, and Avocados*, (2021) Andy Robinson provides a chapter-by-chapter account of how the presence of different commodities influences development policy in Latin America. In one chapter, Robinson explains how the growing rare earths sector in Brazil, within the context of rising geopolitical tensions between the United States and China, encouraged the Bolsonaro administration to implement various policies to increase the rate and scale of niobium exports. With the Brazilian firm CBMM, located in the state of Minas Gerais, controlling the vast majority of the global niobium industry, the author explains how the firm's market share influences both domestic and foreign policy because of its privileged relationship with the Brazilian state. The author cites specific examples of alliances between actors in the public and private sector within the context of a statist developmental model, largely under but not exclusive to the Bolsonaro administration, that has translated into legislative initiatives favorable to the sector at the expense of local and environmental stakeholders.

Overall, the prior research suggests links between critiques surrounding foreign investment in Latin America and issues regarding the lack of regulations limiting negative externalities associated with human and environmental costs of the REE sector. Over time, we can track patterns of increasing relevance of mineral mining, and over the past few years, an increasing discussion on rare earth minerals—concluding with Purdy and Castillo (2022). We hope to elaborate upon the research precedent established by these authors by using concrete case studies to provide policy recommendations to maximize the viability of Chile's burgeoning rare earths sector while managing its negative externalities.

Part II: Geopolitics and REEs

Given their vast technological and industrial applications but limited mining operations, demand for rare earths is increasing faster than supply, putting upward pressure on the price[6]. Geopolitical factors affect the price stability in the global REE trade. The concentration of the REE industry in relatively few countries makes this trade particularly exposed to geopolitical instability, meaning that single market actors have a disproportionate influence over global prices of rare earths compared to other commodity trades. China currently maintains a near-monopoly over the REE trade and has previously "weaponized" this position by restricting exports in retaliation for a jurisdictional dispute which had significant ramifications on the global economy. Given the significant leverage China holds over the global rare earths trade, countries around the world have made diversifying supply chains involving REE a policy priority to hedge against and insulate themselves from geopolitical risks.

Despite the globalized nature of REE supply chains, divergent governance models and institutional arrangements between the public and private sector across various countries translates to a geopolitical environment where certain countries can better assert themselves within the global REE industry than others. The concentration of the REE sector means that commodity exporting countries typically conceptualized as "policy takers" have become "policy makers" in terms of their degree of influence over advanced supply chains. While the scale of the global copper trade, for example, is much larger than that of rare earths, the percentage of market share between the top 10 copper producers is relatively evenly distributed, with Chile being the largest exporter producing 27% of the mineral compared to the second largest, Peru, at 10%[7] in 2022. In the rare earth sector, however, China alone accounted for 63% of raw ore exports in 2022, followed by Myanmar in second place[8]. Notably, although China dominates the REE global trade overall, certain countries like Brazil have carved out a niche over specific rare earths, producing 88% of the world's niobium for example. However this "monopoly within a

[6]Holman, Jacqueline. 2022. "Rare Earth Element Prices to Remain Strong as Demand Exceeds Supply: Ionic." May 13, 2022. https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/051322-rare-earth-element-prices-to-remain-strong-as-demand-exceeds-supply-ionic.
[7]Venditti, Bruno. 2022. "Which Countries Produce the Most Copper?" World Economic Forum. December 12, 2022. https://www.weforum.org/agenda/2022/12/which-countries-produce-the-most-copper/.
[8]Seligman, Lara. 2022. "China Dominates the Rare Earths Market. This U.S. Mine Is Trying to Change That. - POLITICO." 2022. https://www.politico.com/news/magazine/2022/12/14/rare-earth-mines-00071102.

monopoly" is limited to a single element, and therefore, does not fully undermine China's overall control of the global REE trade.

China's Influence in the Global REE Trade

While the country currently holds significant leverage over REE supply chains, China did not always dominate the global rare earths trade. Although certain REEs were discovered nearly two centuries prior, the technological applications making this industry economically viable were not developed until the 1940s. In this period, scientists in the United States took interest in researching the radioactive properties of certain rare earth elements as part of the nuclear weaponry Manhattan Project. Research into REEs necessitated secret, small-scale domestic mining operations to source these minerals. Over time, scientists developed chemical ion exchange procedures that could separate and purify individual REEs[9], laying the foundations for a burgeoning domestic REE mining industry. Initially used in the defense sector, demand for REEs grew exponentially within the context of the Cold War, motivating countries with their own nuclear ambitions, like the Soviet Union, to develop domestic rare earth industries themselves.

As technological applications for rare earths grew beyond the defense sector, these minerals became integral components of consumer electronic products. By the 1960s, with a robust domestic manufacturing sector and growing national defense budget, the United States developed a monopoly over the global rare earths sector; by 1980, "99 percent of the world's heavy REs were a byproduct of U.S. mining operations"[10]. During this same period, however, China liberalized its economic model, prioritizing engaging in international trade as a means to achieve national development. Correspondingly, the rising popularity of neoliberal, free-trade policies encouraged Western firms to prioritize profits over the geopolitical risk of outsourcing rare earths supply chains to China, causing both a transfer of technology combined with the nation's investment in developing its own advanced metallurgy systems to eventually outcompete other global market actors in the REE sector[11]. China increased REE output in the

[9]USGS Mineral Resources Program. 2014. "The Rare-Earth Elements—Vital to Modern Technologies and Lifestyles."
[10]Hijazi, Jamil, and James Kennedy. 2020. "How the United States Handed China Its Rare-Earth Monopoly." 2020. https://foreignpolicy.com/2020/10/27/how-the-united-states-handed-china-its-rare-earth-monopoly/.
[11]Zhang, Shuxian. 2022. "Study on Economic Significance of Rare Earth Mineral Resources Development Based on Goal Programming and Few-Shot Learning." *Computational Intelligence and Neuroscience* 2022 (May): 7002249. https://doi.org/10.1155/2022/7002249.

mid-1980s through export tax breaks and significant public sector investment. In 1990, China applied a protectionist approach by "banning foreign firms from mining rare earths within China and restricting foreign participation in processing projects, except in consortiums with Chinese companies"[12]. In the late 1990s, the Chinese government began "applying 'tiered quotas' to discourage the export of raw materials used in high-value products and to incentivize the shipment of materials in downstream products"[13]. In this way, China came to dominate the REE industry as they steadily outcompeted rival markets.

Throughout this period, China consolidated nearly 100 separate rare earths mining and refining operations into a handful of large state-owned enterprises, becoming policy vehicles through which the Chinese government could directly influence the global trade of these minerals. By the end of the 1980s, China overtook the United States in the REE sector, although it did not remain the only global actor in the industry, with China doing so "from its need for nation-building, its territorial politics with the then Union of Soviet Socialist Republics, and its atomic aspirations"[14]. China's REE dominance succeeded through low labor costs and low environmental standards, which translated into low operational costs allowing the country to outcompete all other producers and undercut existing markets. Recognizing the strategic implications of developing a domestic REE industry in this way, the then leader of China and architect of this national development plan, Deng Xiaoping, famously remarked in 1992, "the middle east has oil. China has rare earth metals"[15]. Through a series of policies to strategically center itself into global supply chains, complemented by neoliberal policies permitting Western firms to outsource critical industries abroad, China came to gradually dominate the global rare earths industry, and therefore consolidate a point of strategic leverage over rival countries.

China's monopoly on REEs extends to processing: it is also the largest importer of rare earths, processing and refining some 85% of the global supply[16]. Countries which independently produce rare earths still export the mineral to China for processing, where the refined minerals

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[12]Jorge-Ricart, Raquel. 2023. "Geopolitical Risk: Raw Materials and Technological Dependence." Elcano Royal Institute. March 15, 2023. https://www.realinstitutoelcano.org/en/blog/geopolitical-risk-raw-materials-and-technological-dependence/.
[13]Ibid. Jorge-Ricart, Raquel. 2023.
[14]Fan, John Hua, Akihiro Omura, and Eduardo Roca. 2022. "Geopolitics and Rare Earth Metals." *European Journal of Political Economy*, December, 102356. https://doi.org/10.1016/j.ejpoleco.2022.102356.
[15]Chu, Dian L. n.d. "Seventeen Metals: 'The Middle East Has Oil, China Has Rare Earth.'" Business Insider. Accessed April 10, 2023. https://www.businessinsider.com/seventeen-metals-the-middle-east-has-oil-china-has-rare-earth-2011-1.
[16]Op. Cit. Seligman. 2022.

are either used in the nation's domestic manufacturing sector or exported to other nations to produce value-added goods. For example, Brazil has a near-monopoly over the production of niobium, but the vast majority is exported to China to be refined. This gives Brazil a specific point of leverage in its relationship with China, while simultaneously proving a strategic vulnerability as no other nation has the capacity to refine niobium at such a scale, forming a mutually dependent trade relationship. As even rare earths produced outside of the nation must pass through China to be refined, China maintains a significant geopolitical leverage over nearly every other nation — controlling the means of production for their technology, green energy, and defense sectors. The concentration of rare earths production correlates to a country's degree of leverage over global trade, and therefore its ability to assert influence over countries specializing in goods higher up the value chain, becoming a unique point of geopolitical leverage for commodity exporting countries but a strategic risk for more advanced economies.

Critical Mineral Policy

Threatened by China's leverage over global supply chains, countries around the world have become increasingly interested in developing critical mineral policies to insulate themselves from geopolitical instability. Because of the widespread applications for rare earths, but the contentious geopolitics surrounding the industry, control of these critical minerals has become a question of control over renewable energy, defense, along with industrial and technical industries. Figure 2.1 depicts the minerals declared critical by the United States, the European Union (EU), and Japan—which other than China, represent the world's largest consumers of REEs.

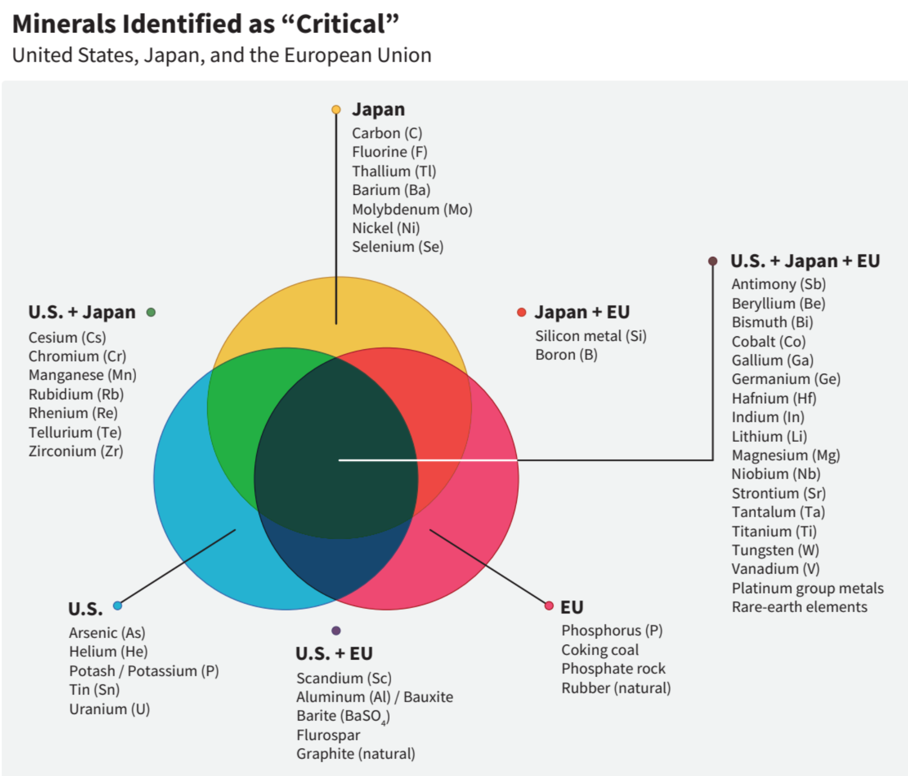

Figure 2.1. Minerals Identified as "Critical"[17]. Source: Jane Nakano, "The Geopolitics of Critical Mineral Supply Chains".

[17]Nakano, Jane. 2021. "The Geopolitics of Critical Mineral Supply Chains." *Center for Strategic and International Studies*, March.

As a result of divergent national priorities, the critical minerals lists of the EU, Japan, and the USA overlap significantly but not entirely. Given the concentration and unique characteristics of the rare earths industry, countries may even be forced to make policy decisions to secure critical minerals at the expense of prioritizing other national interests. After a dispute between China and Japan in 2010 related to competing claims over a fishing jurisdiction, China halted the export of rare earths ores, salts, and metals to Japan in retaliation. The United States was also indirectly impacted because it imports many final products from Japan produced with REEs[18]. Although the initial jurisdiction dispute itself was relatively small in scale, China's disproportionately larger reaction, essentially preventing Japan from importing the minerals necessary for the nation's economically critical technology manufacturing sector, validated global fears that China could eventually "weaponize" its control over rare earths. As a result, prices for rare earths skyrocketed in 2010 as countries competed for a limited supply of these minerals on the global market — as seen in Figure 2.2. Since 2010, countries around the world have intensified their efforts to secure critical mineral resources, expanding their lists to include rare earths in particular.

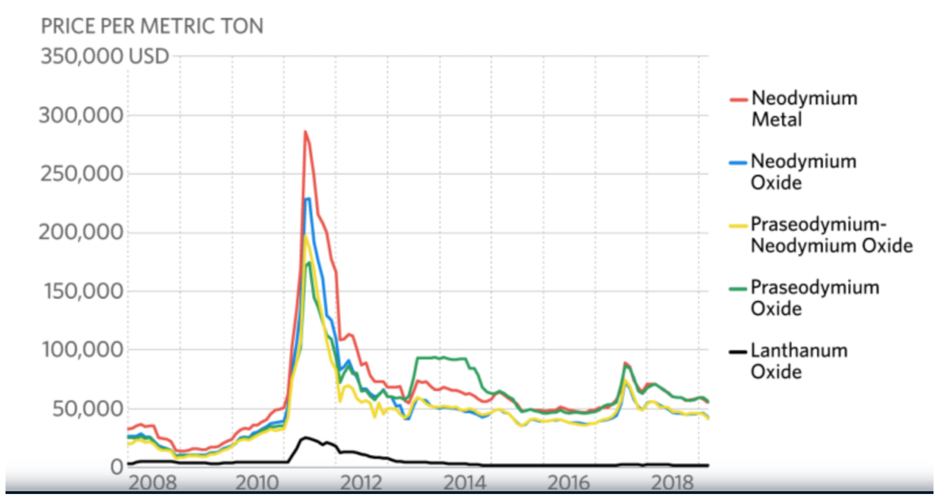

Figure 2.2. Prices of Select Rare Earth Element Ores[19]. Source: Stratfor.

[18]Stratfor. 2019. "The Geopolitics of Rare Earth Elements." https://worldview.stratfor.com/article/article/geopolitics-rare-earth-elements.
[19]Ibid. Stratfor. 2019.

The disconnect between the motives behind securing critical minerals and actual policy implementation vary by nation; however, despite nearly a decade since the country first weaponized its control over the rare earths sector, China still holds significant leverage over global supply chains. Informed by their divergent relationships with China as REE importing nations, the United States views critical mineral policy through the lens of national defense, while the EU and Japan prioritize the economic implications for their domestic industrial sectors. Critical mineral policy is determined by national interests; even allied countries with convergent interests in some policy areas may conflict in others. Within the context of the rising geopolitical tensions, for example, the United States has repeatedly promoted the global diversification of REE mining to prevent substantial import dependence on a single supplier —such as China — that could be exploited geopolitically[20]. These defense implications include both physical capacity in terms of resource availability, and a more intangible form of control over the resource in terms of soft power influence. As a result, the Biden administration has gone as far as to encourage critical mineral stockpiling — in October 2022, the US Department of Energy, Department of Defense, and Department of State signed a memorandum of agreement (MOA) to coordinate "stockpiling activities to support the U.S. transition to clean energy and national security needs"[21]. Although similarly threatened by China's domination of the rare earths trade, the EU and Japan have a more narrowly defined list of critical minerals, primarily concerned with "securing uninterrupted access to affordably-priced critical minerals and processed materials to protect their industrial competitiveness and domestic manufacturers"[22].

Concerned with insulating its economy from another potential "weaponization" of rare earths exports, the EU increased the number of minerals considered critical from 14 in 2011, to 20 in 2014, to 27 in 2017, and to 30 in 2020; In 2017, the EU created the Raw Materials Alliance to "diversify the importation of these materials and their better access within the internal market"[23]. Furthermore, the United States, "in part due to wariness of its defense technology

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[20]Op. Cit. Nakano. 2021.
[21]The White House. 2022. "FACT SHEET: Securing a Made in America Supply Chain for Critical Minerals." The White House. February 22, 2022. https://www.whitehouse.gov/briefing-room/statements-releases/2022/02/22/fact-sheet-securing-a-made-in-america-supply-chain-for-critical-minerals/.
[22]Op. Cit. Nakano. 2021.
[23]European Commission. 2020. "COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Critical Raw Materials Resilience: Charting a Path towards Greater Security and Sustainability."

relying so heavily on China"[24], opened and won a World Trade Organization case against China. As a result, China removed export quotas on rare earth elements in 2015.

Since the export ban on Japan in 2010, the rest of the world has sought alternative suppliers of REEs. By breaking down the REE industry across market lines, we assess the major geopolitical reasons for diversifying the market—as different importers are concerned with different factors. The geopolitical interest for both importing and exporting countries can be divided into three major motivations:

1. Defense
2. Green Technology
3. Technology and Industrial Applications

Defense

Given rising geopolitical tensions with China and the current Russia-Ukraine conflict, the United States government has framed its critical mineral policy in terms of national defense. However, public sector efforts to encourage private sector actors to diversify rare earths supply chains have been met with limited results. Strategically vulnerable industries do not command enough market share to influence overall supply chain diversification because the technology and green energy sectors are larger in scale relative to the defense industry. Despite this, private sector actors in the defense industry and the United States government share a mutual interest in diversifying rare earths supply chains. This differs from China's model, under which the state manages both national defense policy and military equipment production. Conversely, publicly traded defense companies based in the United States balance profit motives, shareholder concerns, and US national defense policy as they pertain to sourcing rare earths. Although both the public and the private sector are theoretically interested in diversifying rare earth supply chains from China, the lack of a viable sourcing alternative has limited the efficacy of current efforts.

The defense sector comprises a relatively small percentage of total rare earths consumption in the USA. As such, consumer products and the green energy sectors, which are less politically exposed, dictate market trends impacting rare earth sourcing—historically leaving the defense sector vulnerable. For example, the United States, via Executive Order 14017 (E.O.) signed in 2021, ordered a review of potential vulnerabilities in critical mineral and material

[24]Op. Cit. Stratfor. 2019.

supply chains, which found an over-reliance on foreign sources and 'adversarial nations' — ie, China — declaring them to be national and economic security threats. This concern, however, is not unfounded as China later threatened to withhold REEs from the US in response to tariffs put in place by former US President Donald Trump[25]. As a result, the most recent National Defense Authorization Act (NDAA) "prohibited U.S. defense agencies from purchasing permanent magnets from China… but the U.S. defense sector… is not big enough to single-handedly drive the market to prioritize alternative production sources"[26]. Despite public sector interest in diversifying supply chains, there remains few viable alternate REE sourcing destinations to fully insulate the USA's defense sector from China's leverage over the global rare earths trade.

Efforts to increase the scale of the USA's domestic REE mining industry to provide the defense sector, among others, with less geopolitically exposed supply chains have been met with significant bureaucratic and economic obstacles. For example, after previously going bankrupt, in response to the 2010 Chinese REE export ban, "the United States' Molycorp mining company reopened Mountain Pass mine in California in 2012, only to declare bankruptcy and shutter the location just three years later"[27]. National defense policy must also be complemented by sufficient government support to either help domestic firms establish new mining operations locally or source minerals from less contentious countries. Without this support, the United States defense sector will continue to rely on rare earths sourced from China. Countries like Chile, with economically viable reserves and alliances with the United States, could hold significant geopolitical leverage in the growing rare earths sector.

Green Technology

The green energy transition poses significant geopolitical risks if supply chains remain undiversified, exchanging one strategic vulnerability for another. While countries become less dependent on oil and diminish their reliance on potentially adversarial countries in this sector, new challenges will emerge as new market actors in the rare earths sector arise. However, unlike oil, global rare earths deposits remain largely underexploited. As the rise of green technology shifts the global geopolitical balance, the green energy transition could correspondingly concentrate supply chain risk exposures to a select few countries producing rare earth elements.

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[25]Op. Cit. Nayar.
[26]Op Cit. Stratfor. 2019.
[27]Op Cit. Stratfor. 2019.

If rare earths supply chains do not diversify, but as the rate of energy transition accelerates, demand for rare earths from politically contentious jurisdictions correspondingly will increase, further intensifying exposure to geopolitical volatility associated with the concentrated nature of REE supply chains. Furthermore, for the green energy transition to be truly green, the whole supply chain must take environmental factors into consideration rather than doubling down on intensifying extractive active activities in volatile jurisdictions. Countries wishing to expand their rare earths production may be forced to accept a degree of localized pollution inherent to the extractives sector for a proportionally greater degree of macro-level climate change mitigation. As the rate of the green energy transition intensifies, so too will the geopolitical risks associated with the rare earths sector.

Rare earths are becoming increasingly relevant in the discussion surrounding decarbonization – or the shift away from fossil fuels to more renewable forms of energy. On one end, "renewables require more materials per energy output than fossil fuels because they are more decentralized," but "the increase in carbon pollution from more mining will be more than offset by a huge reduction in pollution from heavy carbon emitting fossil fuels"[28]. Rare earths are not only critical to the production of electronic components for the green technology sector, but they also make the overall design of these applications more energy efficient. Because of this, an increase in the quantity of rare earths incorporated into a green technology application corresponds with a net decrease in other minerals needed to achieve, potentially lowering prices and reducing net greenhouse gas emissions. For example, a "$9 investment in niobium, added to steel in cars, will reduce vehicle weight by 100 pounds…save[ing] 2.2 tons of CO2 emissions over the life of the car, offsetting the amount of CO2 necessary to produce the steel in the vehicle"[29]. In the short-term, while the world is still largely dependent on fossil fuels, rare earths will be a critical first stepping stone enabling vehicles to be more fuel efficient and generate less emissions.

For most of the industry's history, the environmental degradation associated with REEs mining has burdened export countries; importer countries often outsourced rare earth extraction to jurisdictions with lower regulatory standards. In this way, rare earths supply chains pose a

[28]News, A. B. C. 2023. "Study: Enough Rare Earth Minerals to Fuel Green Energy Shift." ABC News. Accessed May 7, 2023. https://abcnews.go.com/US/wireStory/study-rare-earth-minerals-fuel-green-energy-shift-96719251.
[29]Abraham, David. 2017. *The Elements of Power: Gadgets, Guns, and the Struggle for a Sustainable Future in the Rare Metal Age*.

double standard for policy makers seeking to balance environment and national security concerns. As extraction and processing move away from China, policymakers are burdened with implementing the otherwise environmentally unfriendly aspects of the green energy transition on home soil[30]. New producers must balance the scale of environmental damages of extraction with a proportionally larger global net benefit of facilitating more energy efficient and affordable end-products.

Securing the social license to operate in the rare earths mining sector, therefore, is critical to not just expanding localized operations, but also to reduce global carbon emissions overall. If the negative externalities of the industry are not properly managed, localized environmental degradation resulting from a poorly regulated domestic REE industry is likely to inspire widespread protest or lawsuits threatening to shut down the entire operation. Strategies to secure this social license to operate are jurisdiction-dependent, although policy makers often find it difficult to justify the tangible impacts of localized environmental degradation as a means to achieve the more abstract policy goal of guaranteeing national security or fighting climate change. With that said, advances in mining and processing of REEs funded by favorable governments and the private sector bode well for the REE industry, and methods of extraction are becoming more and more sustainable.

Both public and private actors in the REE industry have focused on reducing the strategic vulnerabilities and environmental concerns posed by the green energy transition. Recycling REEs from spent batteries, for example, can help to limit environmental concerns surrounding REE production by minimizing the amount of raw ore that needs to be extracted and refined; further developing burgeoning recycling technology initiatives has the potential to generate a "circular economy" to even further insulated from supply chain vulnerabilities. However, these processes are costly and more research is necessary to make REE recycling economically viable and widespread. The recycling of REEs also poses geopolitical tensions—China sued the EU in a World Trade Organization (WTO) lawsuit regarding battery recycling initiatives. While recycling technology has the potential to minimize the amount of new REE needed to satisfy global demand, the scale of these operations has not yet reached a critical mass sufficient to offset the need for new REE mining operations.

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[30]Song, Y., Bouri, E., Ghosh, S., & Kanjilal, K. (2021). Rare earth and financial markets: Dynamics of return and volatility connectedness around the COVID-19 outbreak. Resources policy, 74, 102379. https://doi.org/10.1016/j.resourpol.2021.102379

With climate change becoming an increasingly salient geopolitical vulnerability in itself, outsourcing the local environmental degradation as a result of this extractive industry to jurisdictions with lower regulatory standards undermines the true aggregate sustainability of the entire supply chain. As a result, rather than offering public sector support to establish new rare earths mines domestically under a robust and sustainable regulatory framework, therefore mitigating the negative externalities of green technology production at every step of the supply chain, outsourcing the production of these minerals to potentially adversarial countries has caused the green energy transition to become a source of both national security and environmental concern.

Technology and Industrial Applications

While the defense industries and the green energy transition combined comprise a significant portion of rare earths applications, the production of advanced technologies like electric vehicles, smartphones, and computer chips are the largest consumer of these minerals. Because these technologies are often produced by private sector actors largely concerned with immediate profits rather than international politics, and therefore lacking the political incentives to diversify their supply chains compared to private sector actors in the defense industry beholden to national security interests, the advanced technology sector remains particularly politically exposed. Below, Figure 2.3 outlines the relationship between certain REEs, their uses, and the corresponding geopolitical risks associated with each sector.

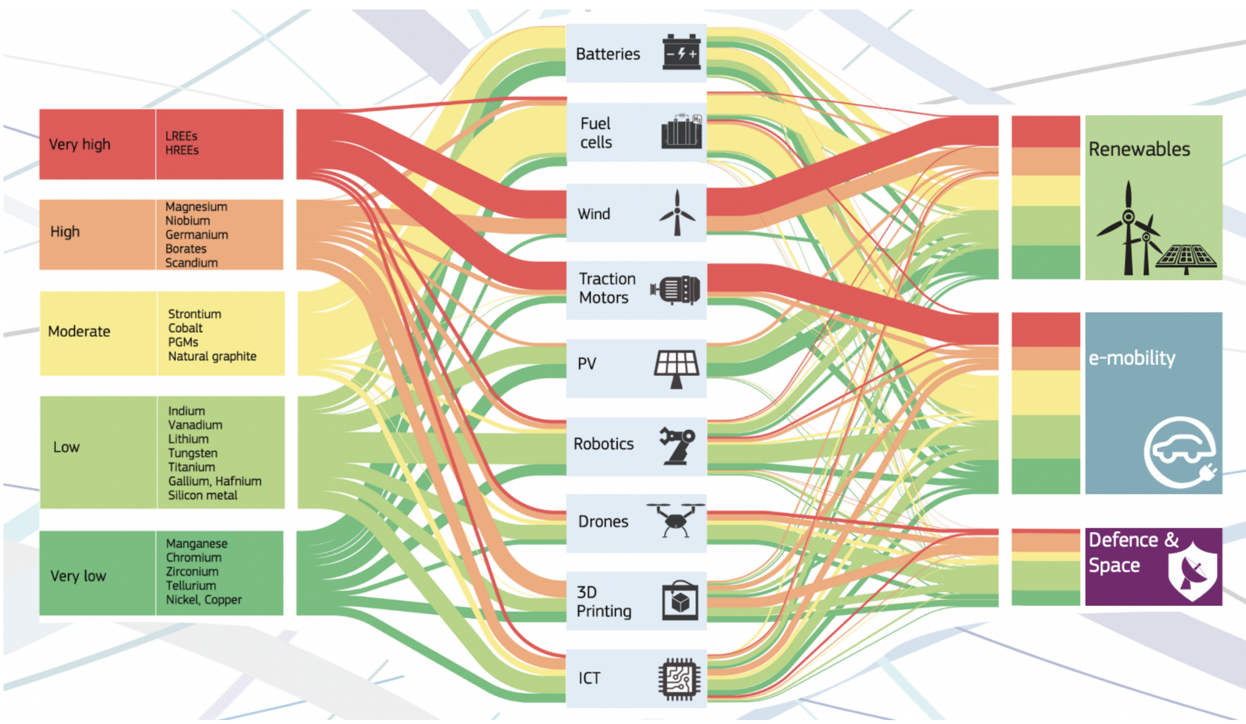

Figure 2.3. Semi-quantitative representation of raw material flows and their current supply risks in nine technologies and three related sectors [31]. Source: European Commission, 2020.

[31]European Commission. 2020. "Critical Raw Materials for Strategic Technologies and Sectors in the EU." https://rmis.jrc.ec.europa.eu/uploads/CRMs_for_Strategic_Technologies_and_Sectors_in_the_EU_2020.pdf.

The rising demand for rare earths has outpaced supply; given the limited amount of new REE mining operations emerging in different countries, market incentives rather than direct policy initiates, have influenced some private sector actors in the technology sector to reduce their total use of rare earths. With limited alternative sources, for example, Tesla announced in March, 2023 that it would reduce the use of REEs in its batteries further, doing so already by 25% since 2017. This is significant because, as the world's largest electric vehicle manufacturer, Tesla's motors and batteries represent 2%-3% of global consumption of permanent magnets which use REEs[32]. Tesla is one of the first major firms not in the defense sector to recognize the geopolitical vulnerabilities associated with relying on potentially adversarial jurisdictions for rare earths. Geopolitical vulnerabilities associated with the concentrated production of rare earths has caused prices of these elements to rise; if less geopolitically exposed jurisdictions like Chile produced rare earths, companies would not have to sacrifice technological advancements and the heightened performance of their products in exchange for limiting the geopolitical exposure of their supply chains.

Although the cost of opening new rare earths mining operations are high, with sufficient public sector support, countries with already robust mining sectors like Chile are well-suited to satisfy this supply and demand gap. As a result, these countries can position themselves as the much coveted alternative rare earths sourcing partner, enabling firms in the defense, green energy, and technology sectors to consume rare earths at desired levels by mitigating geopolitical risks in global supply chains. However, for interest in diversifying rare earths supply chains to translate into action, policy makers must take an active role in facilitating the development of REE mines outside of China.

[32]Houser, Kristin. 2023. "Tesla Switches to Motors without Rare Earth Elements." Freethink. 2023. https://www.freethink.com/transportation/rare-earth-elements-permanent-magnets.

Exporting Countries: Latin America's REEs and China-US-Latin American Relations

With vested interests in the defense, green energy, and technology production sectors, the respective critical mineral policies of the United States, Japan, and the EU are informed by their position as REE importers. However, as nations seek alternate sourcing destinations for REEs, non-aligned regions with vast mineral reserves like the Southern Cone will become increasingly important global trade partners in the rare earths sector. As a result, the work of Douglas and Yates (2020) notes that this "great power" competition has manifested both politically and economically in the Southern Cone of South America. Previous literature by AthenaLab has furthermore noted the geopolitical influence of China in Chile — particularly, that investments have been rapidly expanding and have the potential to change geopolitical power relations in the Americas, who have long shared close relationships with the US[33]. Because of this, as countries increasingly decouple from China economically, access to limited rare earths reserves in the Southern Cone could become increasingly contentious. As global geopolitical volatility increasingly informs domestic economic policy decisions, the political benefits of engaging with the Southern Cone are positioned to eclipse the economic costs of foregoing cheaper REE sourcing destinations like China[34]. Specifically, as countries like the United States decouple from China, Chile — with its large reserves and already robust mining sector — is well positioned to fill the supply/demand gap as an alternative sourcing nation.

Due to economically viable REE reserves being concentrated in a select few countries, rare earths exporting nations hold significant leverage in this trade compared to other minerals. As a result, the critical mineral policies of exporting nations often reflect this strategic position. For example, as a net rare earths exporter, Brazil's critical mineral policy is explicit in its goals to include "the expansion of the country's competitiveness in the international market; Fostering of research, technological development, innovation and entrepreneurship; Promoting cooperation with States, Federal Districts, and Municipalities, as well as mineral sector representatives"[35]. The country's critical mineral policy is wider in scope than that of the EU, Japan, or the USA

[33]Athena Lab. 2023. "Athena Lab." 2023. https://athenalab.org/.
[34]Irwin, Amos, and Kevin P. Gallagher. 2013. "Chinese Mining in Latin America: A Comparative Perspective." *The Journal of Environment & Development* 22 (2): 207–34. https://doi.org/10.1177/1070496513489983, 208.
[35]IEA. 2022. "Decree No. 11.108. Establishes the Brazilian Mineral Policy and the Mineral Policy National Council – Policies." IEA. 2022. https://www.iea.org/policies/16757-decree-no-11108-establishes-the-brazilian-mineral-policy-and-the-mineral-policy-national-council.

because Brazil can harness its leverage as a rare earths exporter to pursue policy goals beyond just securing supply chains.

In order to ensure mineral policy legislation could become actionable, "in 2022, the Brazilian President signed Decree No 11.108 to establish a national mineral policy and to create the Mineral Policy National Council"[36]. Brazil's critical mineral policy is oriented both internally and externally, serving as a policy bridge enabling domestic actors in the private and public sector to export minerals to advance the nation's overall policy goal of using critical minerals exports as a means to facilitate development and guarantee national security. In this way the Brazilian government has a legislative mandate to either negotiate its current trade relationships or seek new partners in response to international and domestic factors. In short, its critical mineral policy recognizes that potentially adversarial countries need Brazil's resources, but Brazil will only engage with these countries insofar as it does not undermine its national security. As a rare earths exporter, Brazil has a significant degree of leverage over its trade patterns compared to importing countries, giving Brazil the ability to influence the behavior of its importing partners in such a way that the United States, the EU, and Japan cannot.

Furthermore, Brazil is able to center itself in other countries' critical mineral strategies because Brazil's largest rare earths export, niobium, is a single mineral with applications across all three strategic sectors: defense, green energy, and advanced technology. In this way, Brazil's monopoly over niobium production casts the mineral's importance to the international commodity trade as both a matter of "national defense" and as a critical resource facilitating "national development". The scale of Brazil's control over the global niobium trade is positively correlated to the degree to which the nation can leverage the mineral as a means to center itself between rival factions to its economic and political advantage. Furthermore, this logic applies to not just geopolitical questions surrounding mineral security, but also global economic rivalries between otherwise friendly countries as well. If a mineral goes to one nation, it is not going to the other. As a result, competing companies in green tech between the USA and the EU often rely on a single REE producing country such as Brazil for niobium.

The expansion of REEs into new countries has enormous potential. Although the motives framing the policy agendas differ, stakeholders around the world have concluded that their overdependence on REE sourced from China is a geopolitical liability. As one of the world's

[36]Ibid. IEA. 2022.

leading mining economies, the EU has turned to Chile, for example, to secure raw material supply chains. Specifically, "in December 2022 the agreement that has secured non-discriminatory access to Chilean raw materials was updated: no exclusive trading rights will be granted to any specific company, as had been the case, nor will the current policy of dual pricing that benefits locally established companies be continued"[37]. With securing access to Chile's mining sector becoming an increasingly important facet of the EU's trade agenda, the United States is similarly positioned to follow suit as the country also seeks to decouple from China. In this way, Chile would be able to lucratively center itself between multiple trade blocs such as the EU, the USA, and China as a neutral supplier of rare earths. This opportunity could create an economic boom for Chile, with the lucrative potential of further economically diversifying by expanding into parallel industries associated with the global REE trade as well. Although China currently dominates, the pace of expansion of this sector in the rest of the world, namely in the Southern Cone, because of rising demand for these critical minerals, is increasing at a rate which may eclipse that of China in the near future if countries like Chile take measures to facilitate the development of their own rare earths sectors.

Our case studies —Brazil, the United States, and Chile —represent three facets of the REE industry. On one hand, Brazil has historical leverage in the mining industry, with booming production of niobium and other critical minerals. The United States is a major importer of REEs, with a growing domestic market and strong geopolitical motivations to diversify its supply sources. Finally, Chile is a burgeoning REE export market and has the potential to develop an economic niche as a rare earths sourcing partner insulated from the geopolitical risks associated with China's leverage over the global trade. At the crux of economics and geopolitics, Chile can profit greatly from this industry. The case of Brazil and the United States provide lessons on the importance of the relationship between the public and private sectors, technology development, and regulatory matters for other countries looking to enter the global rare earths trade.

[37]Jorge-Ricart, Raquel. 2023. "Geopolitical Risk: Raw Materials and Technological Dependence." Elcano Royal Institute. March 15, 2023. https://www.realinstitutoelcano.org/en/blog/geopolitical-risk-raw-materials-and-technological-dependence/.

Part III: Expanding REE Industry Analysis: Economics and Environmentals

As stated, a variety of geopolitical factors have informed the increasing importance of REE related to their technological and industrial applications. Within this context, shifting global trends in the REE sector present both a challenge and an opportunity for countries integrated into critical mineral supply chains. As the dominant actor in the global REE trade, China's decreasing capacity to export rare earths, compounded by a rising global demand for these commodities, has opened space for new market actors to emerge. In order for a country to develop its own domestic REE sector, companies and governments alike must weigh the benefits with the risks of this industry by balancing social, political, and economic factors.

The steady rate of increased global demand, in conjunction with minimal year-to-year price volatility compared to other commodities, make the REE industry an attractive sector for investment and expansion in Latin America. For example, in 2014, the National Geology and Mining Service (SERNAGEOMIN), following an extensive geochemical mapping of the country, announced the discovery of economically viable concentrations of REEs in Chile. This proves to be particularly advantageous as many other countries lack either the reserves, the infrastructure, or the technical expertise to feasibly expand or build an REE industry. As supply chains have become increasingly politicized, public and private sector stakeholder interests must converge to facilitate the development of a country's REE industry, thereby securing the economic license to operate.

As mentioned above, the term "rare earths" is a misnomer; their geological distribution around the world is comparable to that of other more "common" minerals, but the scarcity of concentrated mineral deposits economically viable for extraction is what makes them truly "rare". Countries like Brazil, with an already robust REE industry, are favorably positioned to increase the scale of mining activities to satisfy rising global demand. However, countries like the United States and Chile, with advanced expertise in the mining sector but limited REE industries, have the potential to leverage their technical expertise to develop new mining frontiers in this sector. Because the global trade of REEs is relatively small compared to the scale of other mineral export sectors, but their applications are vast, the importance of these elements to global supply chains is immense. This means that a comparatively minor investment in a nation's REE industry could have a proportionally larger geopolitical and economic impact.

While the economic benefits of the REE industry clearly demonstrate their viability as a mineral commodity export, the existent REE industry shows clear drawbacks: namely, the possibility of environmental harm. In particular, radioactivity often associated with REE mining and processing present severe concerns for the mining industry. Failure to mitigate these issues could cause not only environmental harm, but also damage local communities. In order to address these issues in the recommendations, we outline the major environmental issues generally associated with REE mining.

Global Economics: Favorable Global Trends

The global market is currently in favor of the expansion of REEs, as they are in high demand and prices are correspondingly rising. As discussed in the Comprehensive Guide, REEs have unique structures which make them indispensable to various electrical, industrial, petrochemical, and nuclear applications. China's production capacity, with a unique legal system for the protection and management of rare earths, thus far dominated and outcompeted the global metallurgy market—but while China is the only country with a massive rare earths industry, it is far from the only country with rare earths potential. China's unsustainable practices are draining their resource reserves and their export volume has been decreasing year by year; increasing reserves discoveries elsewhere mean that China will gradually lose its rare earth reserve advantage if new market actors arise[38]. The decrease in China's rare earths capacity provides a unique economic opportunity to countries like Chile — with the reserves and the capacity to expand their industries — as the demand for rare earths is projected to continue growing well into the twenty-first century. And as the green energy transition progresses, but geopolitical tensions remain, the importers of REEs may be more willing to pay slightly higher prices for REEs produced from friendly countries to limit their exposure to China in this sector. In this way, Chile is positioned to leverage its global trade relationships and benefit economically from developing its domestic REE sector.

With a limited number of exporters, but a growing amount of applications and overall demand as their use expands across various sectors, the aggregate price and value of rare earths has correspondingly increased. As seen in Figure 3.1 (below), REE prices have begun to increase over the past four years— with some, like neodymium, a mineral essential to manufacturing

[38]Op. Cit. Zhang.

digital devices like smartphones — skyrocketing to more than $2000/kilogram. For context, other minerals used in similar electronic applications, like copper, trades at just under $9/kilogram[39]; the highly coveted mineral lithium trades at $31/kilogram[40]. Figure 3.1 shows a positive trend in REE pricing since 2018.

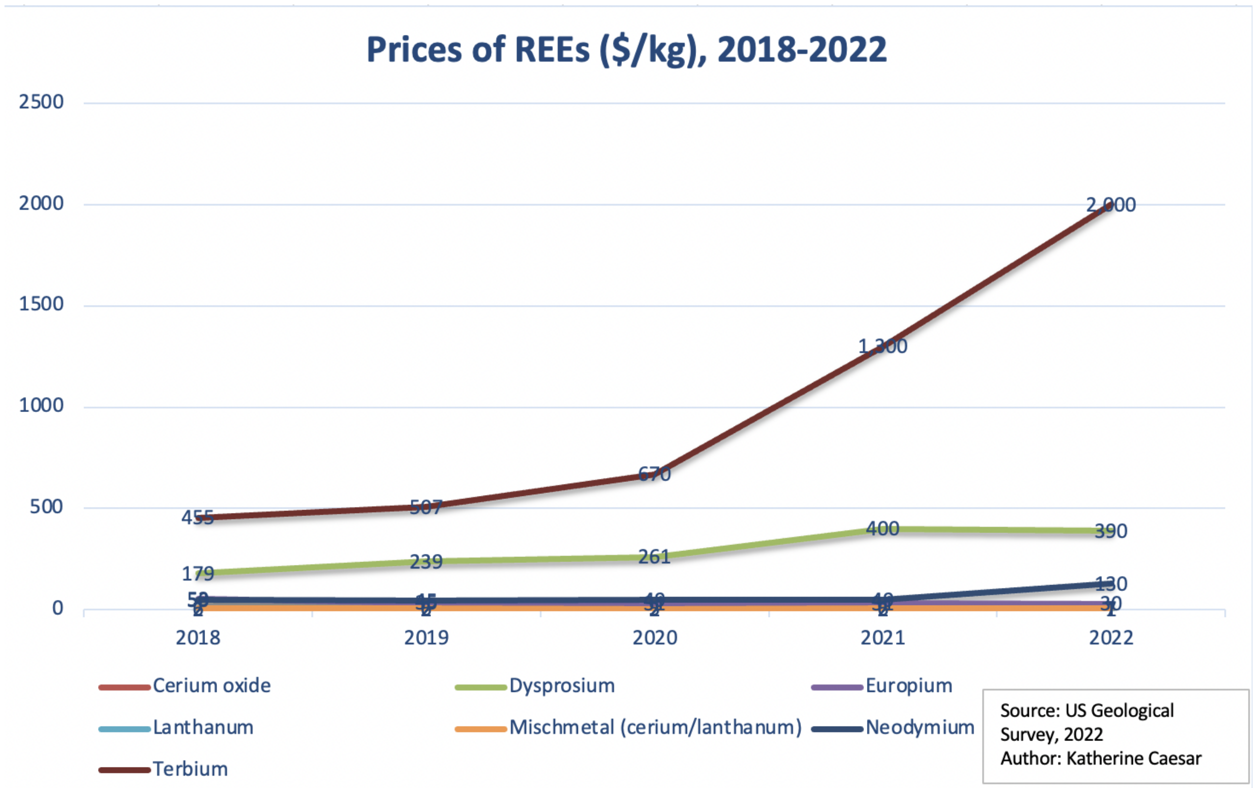

Figure 3.1. Prices of REEs, Dollars per Kilogram, 2018-2022. Source: US Geological Survey 2022, Author: Katherine Caesar.

The demand for REEs has grown in the green technology sector and advanced technological industry alike. In March 2023, the Intergovernmental Panel on Climate Change convened by the United Nations produced a report on global climate change, noting that the earth is likely to cross a critical threshold for global warming within the next ten years[41]. The report emphasizes the need to turn away from fossil fuels, such as coal, oil, and natural gas, and a need to shift to net-zero emissions — that is, no longer emitting greenhouse gasses into the Earth's

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[39]Markets Inside. 2023. "Copper PRICE Today | Copper Spot Price Chart | Live Price of Copper per Ounce | Markets Insider." Accessed April 7, 2023. https://markets.businessinsider.com/commodities/copper-price.
[40]Daily Metal Prices. n.d. "Daily Metal Price: Lithium Price (USD / Kilogram) Chart for the Last Year." Accessed April 7, 2023. https://www.dailymetalprice.com/metalpricecharts.php?c=li&u=kg&d=240.
[41]Lee, Hoesung. "Synthesis Report of the IPCC Sixth Assessment Report (AR6) : Summary for Policymakers." https://report.ipcc.ch/ar6syr/pdf/IPCC_AR6_SYR_SPM.pdf

atmosphere. As the world also moves away from fossil fuels, the energy sector's demand for critical minerals used in green energy applications is expected to increase six fold by 2040[42]. Although the proportionally small scale of the sector relative to the costs of extraction previously disincentivized market actors from investing in the industry, if global demand and the corresponding commodity prices increase at current rates, leveraging the extensive REE deposits in the Americas will become as economically viable as it is geopolitically strategic.

Song et al. (2021) researched the volatility of REEs through "spillovers between the rare earth index and five key financial markets covering clean energy, world equity, base metals, gold, and crude oil" from September 21, 2010 to August 28, 2020[43]. The authors found that steady growth of REEs is predictable and agree with the IEA's (International Energy Agency) forecasts that demand for REEs and other strategic minerals needed for the green energy transition is expected to quadruple by 2040[44]. Furthermore, the researchers and the IEA predict that key REMs like neodymium and dysprosium will face supply shortages in coming years — noting a need for increased extraction in those sectors. Because overall exports of REEs from China are decreasing, but the global market for these minerals is increasing in scale and value, securing rare earths supply chains in such a way that insulates them from geopolitical tensions to facilitate further technological advancement and the green energy transition has become a policy priority for countries around the world.

[42]IEA. 2021. "Clean Energy Demand for Critical Minerals Set to Soar as the World Pursues Net Zero Goals - News." IEA. Accessed April 7, 2023. https://www.iea.org/news/clean-energy-demand-for-critical-minerals-set-to-soar-as-the-world-pursues-net-zero-goals.
[43]Op. Cit. Song. 2021.
[44]Ibid. Song. 2021.

Chile's Stake in the REE Industry

Chile could particularly benefit from expanding into the REE market due to its large existent mining sector, quality and quantity of mineral deposits, and solid legal framework for developing REE-specific legislation. Furthermore, REE production would help to diversify the Chilean mining sector which is particularly reliant on a single mineral: copper. Importantly, like Chile's other mining activities, the REEs sector can certainly be profitable. However, it is important to note that only a relatively small amount of REEs are used in their respective applications compared to other more common minerals. As a result, the overall global scale of the rare earth trade is valued at $2.7 billion[45] compared to Chile's other largest mining sectors—copper and lithium—globally valued at 16.1 billion[46] and at $7 billion[47] respectively. In Part II, we established that there is a growing international demand for REEs, and that countries are willing to pay above prior market value rates to diversify the REE market from China. Countries such as the United States have called for friend-shoring, or for friendly nations to increase their production of REEs necessary for its domestic defense, green energy, and advances technology sectors[48].

Although the scale of the global REE trade is relatively small compared to other minerals, the growing number of applications for rare earths has caused production of these minerals to drastically increase in the past few decades. However, despite the rapid scale of the trade, it still falls short to fully satisfy the global consumption of rare earths, causing prices to correspondingly increase despite a consistent growth in supply. Figure 3.2 (below) demonstrates the growth in World Production of REEs from 1900 to 2019. As seen below, the global production of REEs has skyrocketed in recent years, signaling the increase in demand and the viability of the REE market.

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[45]OEC. n.d. "Rare-Earth Metal Compounds | OEC." OEC - The Observatory of Economic Complexity. Accessed April 7, 2023. https://oec.world/en/profile/hs/rare-earth-metal-compounds.

[46]OEC. n.d. "Raw Copper | OEC." OEC - The Observatory of Economic Complexity. Accessed April 7, 2023. https://oec.world/en/profile/hs/raw-copper.

[47]ReportLinker. 2023. "Global Lithium Market to Reach $22.6 Billion by 2030." GlobeNewswire News Room. March 8, 2023. https://www.globenewswire.com/news-release/2023/03/08/2623219/0/en/Global-Lithium-Market-to-Reach-22-6-Billion-by-2030.html.

[48]Part IV: The United States.

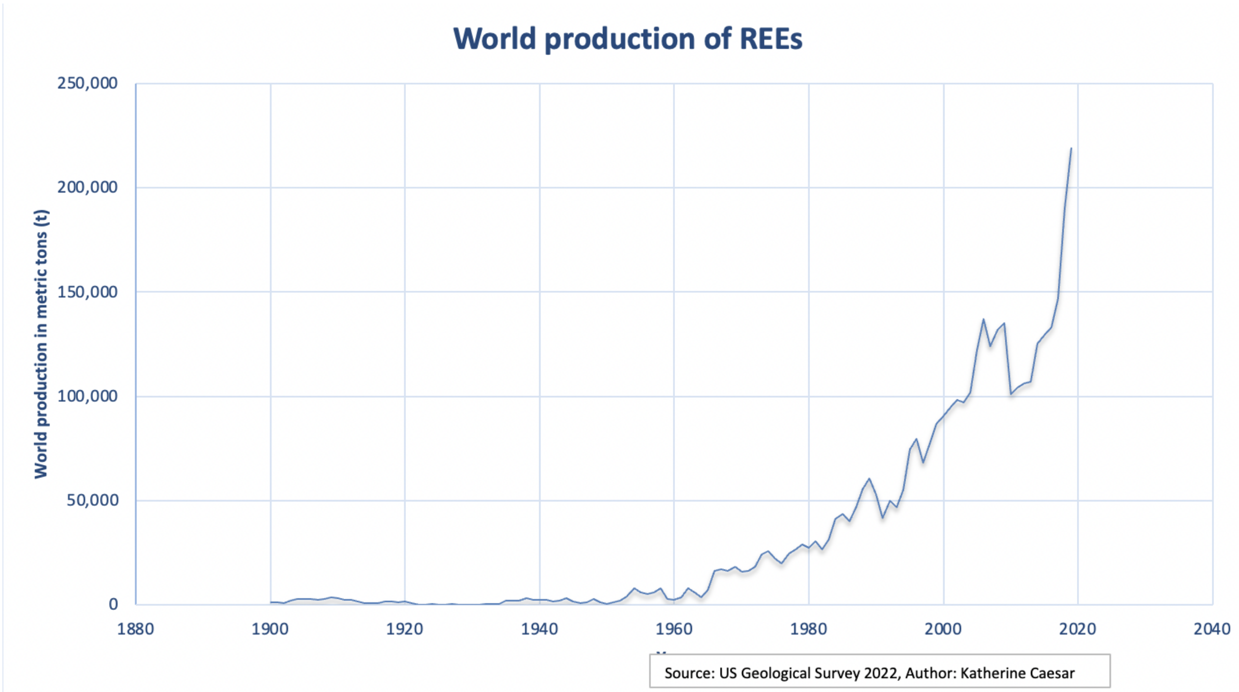

Figure 3.2. World production of REEs. Source: US Geological Survey 2022, Author: Katherine Caesar.

Figure 3.3 (below) demonstrates the annual percentage of GDP growth in Chile between the years of 2000 and 2021. As seen below, the GDP during the 2020 COVID-19 pandemic decreased rapidly by a rate of -5.98% before increasing by 11.67% between 2020 and 2021, returning to surpass the mean[49]. Chile's mining sector represents 15% of the overall GDP, and mineral exports represent 33.26% of Chile's export sector, or over $24 million in exports per year. Chile mainly exports to China, representing 38.85%, and the United States, representing 13.20 percent of exports[50]. Chile's export relationships with both China and the United States would provide two potential export markets for its domestically produced REEs. Furthermore, as discussed in Part V, Chile's quality and quantity of minerals and infrastructure could feasibly facilitate the development of a corresponding domestic REE refining sector, which would maximize profits by producing value-added products.

[49]The World Bank. n.d. "World Development Indicators | DataBank." Accessed May 7, 2023. https://databank.worldbank.org/source/world-development-indicators.
[50]Ibid. The World Bank.

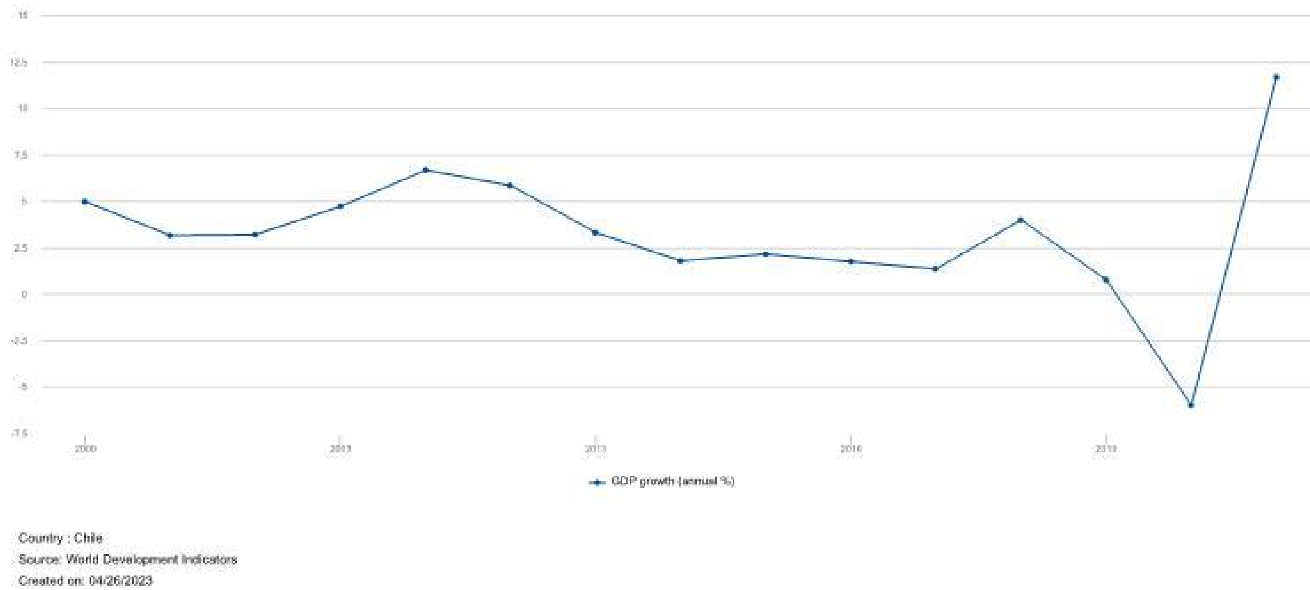

Figure 3.3. GDP Growth of Chile. Source: World Development Indicators, Author: Katherine Caesar.

Figures 3.4 and 3.5 (below) depict the unit price changes in copper, lithium, and REEs in dollars per ton between 1990 and 2019, and 1960 and 2019, respectively. Both figures demonstrate a price crash after 2019, attributed to the fall of the global economy with the onset of the COVID-19 pandemic. Our dependent variable for both models is the unit price, and the independent variable is the time in years. REEs are depicted in dark blue, copper in turquoise, and lithium in red. The trend lines, represented by the dotted lines, show the average change in price within this time period. The R^2 value (“R” squared value) represents the proportion of the variation in the dependent variable in relation to the independent variable. The closer the R^2 value is to 1, the higher the confidence level in the relationship between the variables—in this case, a higher correlation between price increases over time. Through these models, we are able to assess the change in pricing over time for REEs, copper, and lithium, as well as discuss their volatility throughout these time periods.

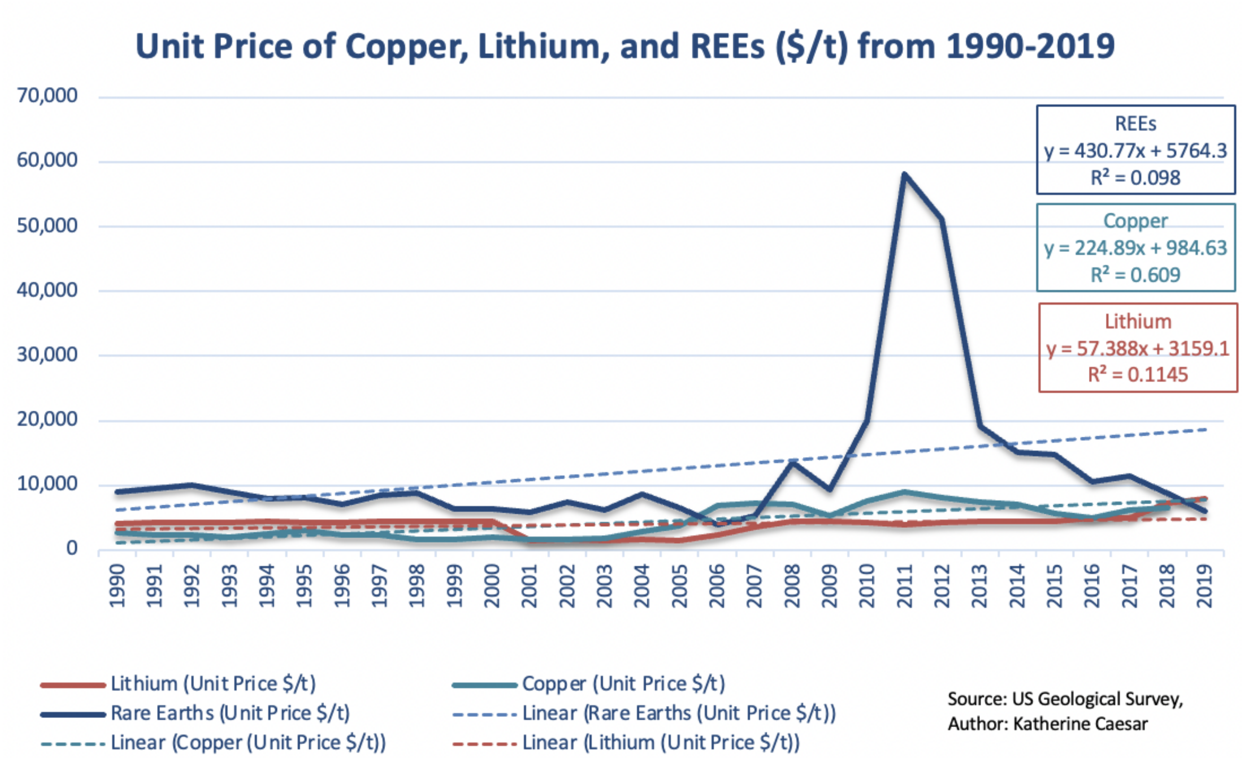

Figure 3.4. Unit Price of Copper, Lithium, and REEs ($/t) from 1990-2019. Source: US Geological Survey 2020, Author: Katherine Caesar.

The solid colored lines represent the unit prices of each metal. As shown in Figure 3.4, the unit price of REEs is consistently higher than that of copper or lithium. Furthermore, the REE trend line between 1990 and 2019 trends upwards with a slope of 430.77. The R^2 value of the REE trend line is 0.098, representing a fairly low confidence in the trend line. This low confidence is likely the result of the spike in 2010, as discussed in Part II. The 2010 dispute between China and Japan caused a massive geopolitical crisis, skewing the results for REE pricing in this period. The copper trend line has a slope of 224.89, about half that of REEs. The R^2 value of copper is 0.609, representing a rather high confidence level corresponding to a relatively low volatility in this time period. The lithium trend line has a slope of 57.388. The R^2 value of lithium is 0.1145, also representing a fairly low confidence in the trend line and does not show very much growth over time. These findings demonstrate that REEs have been increasing at a faster rate than either copper or lithium—and that prices for REEs are historically much higher than the other metals, demonstrating the industry's potential economic viability for Chile.

To confirm our results from Figure 3.4, we also correlated unit prices changes by year across a greater period of time—from 1960 to 2019. Again, REEs are depicted in dark blue, copper in turquoise, and lithium in red.

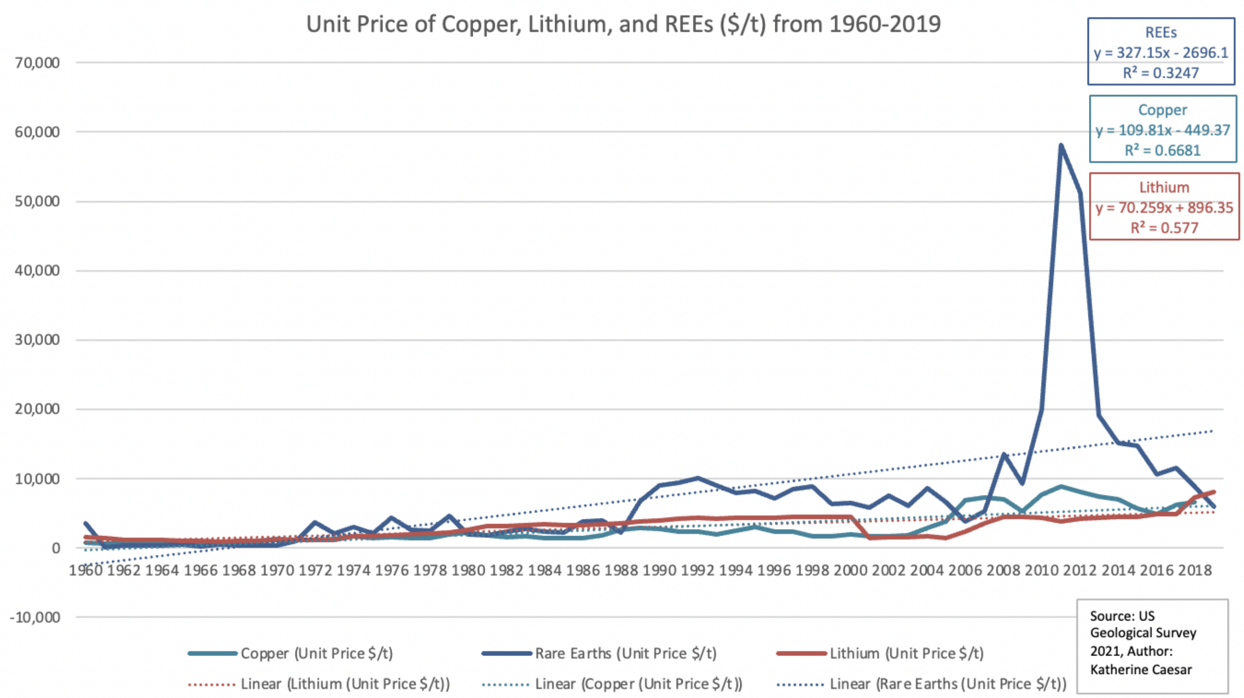

Figure 3.5. Unit Price of Copper, Lithium, and REEs ($/t) from 1960-2019. Source: US Geological Survey 2020, Author: Katherine Caesar.

The solid lines demonstrate that across this time frame, REE values in price per ton have consistently surpassed that of copper and lithium. The REE trend line between 1960 and 2019 trends upwards more steeply than either copper or lithium, with a slope of 327.15.77. The R^2 value of the REE trend line is .3247, representing a confidence lower than that of copper, but much higher than that of Figure 3.4, demonstrating less volatility over time. The copper trend line between 1960 and 2019 has a slope of 109.81, still representing less growth than the REE trend line. The R^2 value of copper is 0.6681, representing a rather high confidence level corresponding to a relatively low volatility in this time period. The lithium trend line between

1960 and 2019 has a slope of 70.259. The R^2 value of lithium is 0.577, representing a fairly high confidence. The 2010 rare rarths dispute skewed the trend lines in both Figures 3.4 and 3.5 and contributed to a low confidence in the R squared results in both charts—correlating to a high amount of price volatility in these time periods. However, both figures show that the growth rate of REEs remains on an upward trend, and seem to have returned to the mean in 2019 (before crashing in 2020 with the onset of COVID-19).

Chile's copper industry is a major source of income for the country. However, the annual average copper price in 2021 was $4.23 per pound[51], while the average prices of some REEs such as terbium reach over $589.670 per pound[52]. Copper pricing is considered a barometer for the global economy—meaning that the state of the global economy is reflected through copper pricing, with higher prices in a stronger global economy and lower prices when the global economy is weaker. Copper prices are projected to remain relatively stable throughout 2023 and 2024[53], while REE prices are projected to increase rapidly[54]. In comparison to copper and lithium, Figures 3.4 and 3.5 show that REEs are growing at a much faster rate and are worth hundreds of dollars more per ton than copper.

It is important to note that unit price over time does not directly correlate to industry profitability. Although the price of each unit of REEs on average is much higher than that of copper or lithium, companies looking to begin this industry will face production and processing costs. As we will discuss in the recommendations section (Part V), private and public sector interactions, including funding for research and development, could offset these up-front costs.

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[51]International Trade Administration. 2022. "Chile - Mining." September 30, 2022. https://www.trade.gov/country-commercial-guides/chile-mining.

[52]USGS. 2022. "Mineral Commodities Summary."

[53]Smith, Elliot. 2022. "Copper Prices — Traditionally a Barometer for the Global Economy — Are Expected to Soar next Year." CNBC. December 13, 2022. https://www.cnbc.com/2022/12/13/copper-prices-traditionally-a-barometer-for-the-global-economy-are-expected-to-soar-next-year.html.

[54]Op cit. Song. 2021.

Drawbacks of the REE Industry: Environment and Local Community Concerns

Although the REE industry has positive macro-level implications for the green energy transition, environmentally damaging extractive and refining methods have the potential to cause both air and water pollution, particularly harmful to acute local communities. As a result, if these negative externalities are not sufficiently mitigated, concerns from local and environmental stakeholders in jurisdictions with an active REE industry could manifest into widespread protest or legal action. In this way, we analyze the possible harms of environmental degradation, which could inflame latent social conflicts and community stakeholder concerns, particularly in sensitive jurisdictions such Indigenous territories. Despite the sector's economic potential, suboptimal regulatory frameworks encouraging the use of low cost, environmentally damaging extractive methods are of particular concern because they undermine the overall sustainability of supply chains to develop green technology. This capstone advocates for the importance of respecting community-level concerns regarding the REE industry before they can cause harm, instead of after. As such, we address possible community and environmental concerns regarding the REE industry.

The mining and processing of REEs can be extremely dangerous and can potentially cause severe environmental damages, which can devastate local communities in the areas surrounding these mines—as seen in the contaminated food and damages to human health costs near REE mining sites in the Fujian Province in Southeast China[55]. New technologies in the REE industry could minimize the negative environmental impacts of the extraction and separation process, but such technologies can be costly and many still in the experimental phase of development. While global interest in the region's REEs reserves is new to Latin America, the legacy of the exploitative nature of the mining industry is not. Given this historical precedent, local communities across the region have called for an increase in transparency, accountability, participation, and benefits from mining projects[56].

While abundant in the Earth's crust, separating REEs from other minerals is difficult and costly. As stated, REEs are typically found in small quantities, and bonded to other (less

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[55]Li, Xiaofei, Zhibiao Chen, Zhiqiang Chen, and Yonghe Zhang. 2013. "A Human Health Risk Assessment of Rare Earth Elements in Soil and Vegetables from a Mining Area in Fujian Province, Southeast China." *Chemosphere* 93 (6): 1240–46. https://doi.org/10.1016/j.chemosphere.2013.06.085.
[56]The World Bank. 2010. "Improving Mining Benefits for Communities." 2010. https://www.worldbank.org/en/news/feature/2010/06/15/improving-mining-benefits-for-communities.

valuable) minerals below ground[57]. Both the extraction and refining process of REEs require the use of expertly managed heavy chemicals — with the potential for extreme health and environmental damage if not handled and disposed of properly. Because of the lesser-known nature of the industry, and therefore the inherent regulatory challenges associated with both the mining and refining process, most countries' legislations have not yet adapted to accommodate for the specific conditions of this industry. Often, countries have a broad framework which supervises mining activities in general rather than legislation or regulations specific to the unique nature of the REE sector. For every step of the green energy transition to be truely "green," the rare earths forming the base of the supply chain must be extracted in such a way that does not inflame local or environmental concerns.

Environmental Harm in Extraction and Processing

REEs are most commonly mined in two ways, both of which involve a smelting and separation process which emit significant environmental pollutants. However, given China's dominance over the global industry and lack of concern for the environment, blanket criticism of the REE sector are often informed by the industry trends set by the specific style of extraction used in China[58]. For example, Chinese state policy in the rare earths mining sector prioritizes keeping costs low over environmental protections. One method "removing the topsoil, transporting it to a leaching pond, and adding chemicals (such as ammonium sulfate and ammonium chloride) to separate out the metals. The chemicals used in this separation process can create air pollution, cause erosion, and leach into groundwater"[59]. The second processing method involves "drilling holes into the ground, inserting PVC pipes and rubber hoses and pumping chemicals to flush out earth. The resulting slurry is then pumped into leaching ponds to separate out the rare-earth metal"[60]. Commercial separation is performed by liquid-liquid extraction or ion-exchange methods[61]. Removing the topsoil and pumping chemically altered water into the ground can cause chemical erosion, which can leach through the soil and enter the water table. Furthermore, both processes carry anthropogenic concerns related to their lingering

[57]Op. Cit. Nayar.
[58]Op. Cit. Zhang, 4-5.
[59]Lee, Jordy. 2021. "Rare Earths Explained." Milken Institute Review. July 26, 2021. https://www.milkenreview.org/articles/rare-earths-explained.
[60]Earth.Org. 2020. "How Rare-Earth Mining Has Devastated China's Environment." Earth.Org. July 14, 2020. https://earth.org/rare-earth-mining-has-devastated-chinas-environment/.
[61] Britannica. 2020. "Holmium | Definition, Properties, & Facts | Britannica." 2020. https://www.britannica.com/science/holmium.

effects on the local environment, bioaccumulation in biota, and chronic toxicity[62]. The methods of extraction—namely leaching ponds, which soak REEs metals in order to break them down into components—can severely affect not only groundwater, but also agricultural productivity and human health. The mining of REEs in China causes soil pollution, which matriculates into agricultural lands and concentrating in food and water consumed by local populations, which may cause long-term harm[63].

Outside of China, in countries like Brazil, which lack the administrative capacity to enforce legislation in remote jurisdictions like the Amazon, illegal miners prioritize minimizing the costs of their operations at the expense of the environment or social concerns. Illegal and inefficient extractive systems cause massive environmental damage and "undermine the market by exploiting only the resources that can be easily traded and wasting the rest"— especially since they are not subject to any regulations[64]. Preferring to use the most cost-effective extractive methods without regard for their environmental impact, illegal miners in Brazil "fell trees, use high-grade explosives for blasting soils and dredge riverbeds"[65]. Rather than actively encouraging harmful extraction methods in these jurisdictions, Brazil's regulatory passivity and lack of oversight enables malicious actors to operate with little accountability.

Even legal niobium production in Brazil has been linked to land disruptions, excessive waste materials, and radioactivity—although the US Geological Survey considers these concerns "generally minimal under most natural conditions"[66]. Brazil maintains a robust environmental regulatory framework, but policy inconsistency makes holding market actors accountable a challenge, and environmental enforcement struggles due to corruption and weak state capacity[67]. For example, this lack of enforcement capacity enables organized crime syndicates to use their pre-existing smuggling networks to move illegally extracted minerals out of the Amazon and onto legal international markets. This is a particularly salient issue on Indigenous land in the Amazon where recent government efforts to open the region to legal mining activities has also implicitly encouraged illegal actors to undertake extractive operations under the assumption that

[62]Op Cit. Li et al.
[63]Ibid. Li.
[64]Op. Cit. Abraham, 108.
[65]Op. Cit. Erthal Abdenur.
[66]https://pubs.er.usgs.gov/publication/pp1802M
[67]Erthal Abdenur, Adriana. 2019. "Organized Crime in the Amazon: Illegal Mining Hotspots | Climate-Diplomacy." July 29, 2019.
https://climate-diplomacy.org/magazine/environment/organized-crime-amazon-illegal-mining-hotspots.

they are less likely to be prosecuted. This is not unique to Brazil, however, because for example, "in Colombia, FARC rebels… produce tungsten from the depths of the Amazon jungle… In 2011, about 21 percent of the world's tantalum supply came from regions in conflict, and almost all of it was processed in China"[68]. Although these operations are centered around the illegal gold trade, criminal networks are also involved in artisanal mining operations for coltan (the common name for columbite-tantalite, an ore), which contains rare metals niobium and tantalum. By virtue of the illegality of these operations, minerals mined in this way are not subject to regulatory oversight and cannot operate at an economy of scale to make their extractive methods more efficient. Furthermore, because of this lack of regulatory oversight, illegally sourced rare earths are transported alongside legal shipments of these minerals to China where they are refined and subsequently enter global supply chains. Because shipments of rare earths from various jurisdictions are often processed in a single facility, it becomes impossible to distinguish the origin of these minerals once they are refined together. Given the globalized nature of the industry but lack of regulatory enforcement capacity in opaque jurisdictions, Chinese state policy also gives illegal actors a means to "launder" rare earths even if the country of origin officially prohibits these activities.

Although the most common methods of extracting and processing REEs cause strong environmental concerns, companies worldwide have made some attempts to mitigate harm and adopt more environmentally-friendly policies. For formal operations, Brazil's largest niobium producer, CBMM, demonstrates the possibility of making extractive methods more sustainable. For example, CBMM uses 100% renewable energy to power their mining operations[69]. Furthermore, rather than drawing from the water table, mixing this water with heavy chemicals, and then pumping it back into the ground, CBMM has implemented a state-of-the-art water recycling system which recirculates 96% of the water used[70]. In this way, the company both minimizes both its overall water usage and the environment's exposure to potentially toxic heavy chemicals. Although the company was founded in the 1960s, but only implemented these sustainability systems within the last decade, CBMM has also been able to improve its relationship with the local community by taking measures to limit the human cost of its mining

[68]Op. Cit. Abraham, 48.
[69]CBMM. 2021. "CBMM 2021 Sustainability Report." https://cbmm.com/reports/sustainability-report-2021/assets/docs/CBMM-RS2021_ENG_D8.pdf.
[70]Ibid. CBMM.

operations as well. However, CBMM's sustainability efforts are a single example within an industry that is notorious for its negative impacts on the environment. By virtue of their size, large-scale mining operations like CBMM are more susceptible to public scrutiny, and therefore have a vested interest in at least superficially presenting themselves as environmentally friendly. However, because global interest in finding alternate REE sourcing nations is largely inspired by geopolitical concerns rather than environmental concerns, and given the lack of a globally standardized accountability system like the Kimberly process for diamonds, rare earths produced through small-scale illegal mining operations in opaque juristics like the Amazon still find their way into global supply chains.

Although REEs are most commonly extracted by either topsoil removal and/or pumping chemicals mixed with water into the earth to separate the REEs from other minerals, these are not the only possible methods of extraction. Research and development specific to the REE sector are crucial to limiting the negative impacts of the industry, as companies like CBMM announce more environmentally-friendly competitive business models. These externalities require significant investment in sustainable mining techniques and robust government accountability mechanisms, all of which are extremely costly and time consuming—but commodity prices are no longer the most salient factor determining the global competitiveness for large-scale firms in the rare earths market. Chinese mining techniques have enabled it to outcompete other countries by keeping their operational costs as low as possible by disregarding environmental and social concerns. As relations between China and other countries deteriorate, market actors are becoming increasingly willing to pay a premium to source rare earths elsewhere.

While not unique to the REE industry, environmental degradation in both Chile and the United States has also resulted from unsafe and unsustainable mining practices in their copper and coal industries in each country, respectively, where rare earths are also typically found. Often, sustainability becomes a means to an end to secure foreign investments and business partnerships from actors in jurisdictions with more robust regulatory frameworks. For example, companies often offer reports on their sustainability on their company websites, using illustrative language to seem as green as possible—regardless of the data. A central irony of the green energy transition revolves around the fact that firms producing sustainable end products are often forced to source rare earths from mines responsible for acute localized environmental degradation, undermining the sustainability of the end product itself. Large firms in jurisdictions with weak regulatory enforcement capacity pursue sustainability initiatives insofar as it contributes to their bottom line. Brazilian CBMM, for example, only implemented its sustainability initiatives after lawsuits against the firm related to its prior history of pollution are costly and damage its public image, impacting its ability to solicit foreign investment from actors in jurisdiction beholden to higher regulatory standards. As a result, not only is legislation specific to the unique nature of the rare earths industry necessary, but this legislation must also be accompanied by actionable enforcement mechanisms to hold actors accountable.

Risk of Radioactivity

If left to self-regulate, many actors in the rare earths sector, regardless of their size, only take measures to mitigate the negative externalities of their operations if it ultimately impacts their profitability. While the extractive methods used by the mining industry as a whole are notorious for damaging the environment and inflaming social conflicts, the rare earths sector is particularly contentious because these minerals are often also radioactive. If not managed properly, pre-existing environmental concerns are further compounded by the dangers posed by this radioactivity. The Harvard International Review (2021) reports that for every ton of rare earth produced, the mining process yields 13kg of dust, 9,600-12,000 cubic meters of waste gas, 75 cubic meters of wastewater, and one ton of radioactive residue. Furthermore, for every ton of rare earth, 2,000 tons of toxic waste are produced — usually due to radioactive elements thorium and uranium, which are often bonded to REEs in the ground[71].

The processing of REEs often involves the separation and removal of uranium and thorium, which can result in TENORM (Technologically Enhanced Naturally Occurring Radioactive Materials) waters. TENORM wastes are defined as "naturally occurring radioactive materials that have been concentrated or exposed to the accessible environment as a result of human activities such as manufacturing, mineral extraction, or water processing"[72]. The 'technologically enhanced' part of the acronym refers to the "radiological, physical, and chemical properties of the radioactive material have been concentrated or further altered by

[71]Op. Cit. Nayar.
[72]US EPA, OAR. 2014. "Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM)." Overviews and Factsheets. November 12, 2014. https://www.epa.gov/radiation/technologically-enhanced-naturally-occurring-radioactive-materials-tenorm.

having been processed, or beneficiated, or disturbed in a way that increases the potential for human and/or environmental exposures"[73] — meaning the chemicals could have unprecedented effects as a result of their being manipulated as part of the extraction or processing processes. Substances considered 'TENORM' range from extremely minorly radioactive to high concentrations of radionuclides. Although when handled properly under strict regulatory supervision, there is little risk of exposure to these toxins. However, a precedent of blatant disregard for environmental concerns or regulatory oversights makes this industry particularly contentious in jurisdictions with weak accountability mechanisms.

Regardless of a jurisdiction's regulatory capacity, failure to properly contain radioactive material remains an omnipresent threat. Events of radioactive spills have certainly occurred in REE mining —and the mining industry as a whole. The largest spill of radioactive material in the United States occurred in 1979, when a dam in territory of the Navajo Nation in New Mexico broke, releasing some 4 million tons of uranium ore and 94 million tons of radioactive wastewater into the Puerco River[74]. This water contained 'mill tailings—leftovers with toxic contaminants— "placed in unlined evaporation ponds at the mill site"[75]. The government report revealed that the Navajo Nation raised concerns to a congressional committee in 1993, but their concerns were brushed aside. The GAO report later noted that the drinking water of the area contained radioactive elements, and health effects—including lung cancer, bone cancer, and impaired kidney function— "can result from exposure to elevated levels of uranium and other radionuclides"[76]. Pasternak (2011) wrote a scathing exposé stating that "The IHS (Indian Health Service) and the state urged Navajos not to drink the water nor enter it, nor let their animals do so, anywhere downstream from the spill. But the people by the Puerco didn't have many alternatives"[77]. The accident was the largest radioactive spill in US history, but only in 2008, some thirty years after the incident, the Federal Government and Anadarko Petroleum Corp., the company responsible for the spill, jointly paid a $5.15 billion settlement which required them

[73]Ibid. US EPA.
[74]GAO Report. 2014. "GAO Report on Navajo Uranium Mines." United States Government Accountability Office. Accessed April 20, 2023. https://www.documentcloud.org/documents/1211503-gao-report-on-navajo-uranium-mines.
[75]Ibid. GAO Report.
[76]Ibid. GAO Report.
[77]Pasternak, Judy. 2011. *Yellow Dirt: A Poisoned Land and the Betrayal of the Navajos*.

pay for the cleanup of the radioactive waste[78]. Despite the settlement, local communities report long-term health effects and environmental damages[79].

In Latin America, methods of radioactive waste disposal have similarly failed to protect local communities. In Chile, human rights experts in 2021 criticized the government for the lingering impact of a toxic waste dump by Swedish company Boliden Mineral AB in the northern Chilean city of Arica from 1984 to 1985. Thousands of people in the city were affected by the dump, and reported side effects include “cancer, joint pain, respiratory difficulties, allergies, anemia, miscarriage and birth defects”[80]. The failure of the Chilean government to recognize the severity of the environmental and human cost of the radioactive waste, which to date has not been removed from Arica and continues to affect inhabitants[81]. Human rights agencies continue to pressure the government to provide support for the low-income community affected by the radioactive waste.

In Brazil, similar concerns with radioactive waste in its rare metals industries abound; Da Costa Lauria et al. (2005) raised concerns with enhanced levels of radioactivity in residues and wastes of monazite, an ore containing the rare earth minerals cerium and thorium. Since the 1980s, the Brazilian government has stored this radioactive waste in buried concrete tanks, temporary storage buildings, and sealed trenches[82]. Furthermore, the niobium industry in Brazil raises concerns of radiation and radioactive wastes, as niobium mining produces massive quantities of non-processed waste (NPW) each year[83]. However, despite the scale of the industry, there are no regulations in Brazil’s mining code which specifically detail how niobium’s radioactive byproducts and non-process waste should be handled[84]. Rather, this supervision is left up to the Brazilian Association of Technical Standards (ABNT), a private non-profit organization and normative body which is responsible for establishing technical standards in Brazil[85].

[78]Jennings, Trip. 2014. “Remembering the Largest Radioactive Spill in U.S. History.” New Mexico In Depth. July 7, 2014. https://nmindepth.com/2014/remembering-the-largest-radioactive-spill-in-u-s-history/.
[79]Op. Cit. Pasternak.
[80]OHCHR. 2021. “Chile: Nearly 40 Years on, Still No Remedy for Victims of Swedish Toxic Waste – UN Experts.” OHCHR. Accessed April 20, 2023. https://www.ohchr.org/en/press-releases/2021/06/chile-nearly-40-years-still-no-remedy-victims-swedish-toxic-waste-un-experts.
[81]Ibid. OHCHR.
[82]Op. cit. Da Costa.
[83]El Hajj, Thammiris Mohamad, Mauro Pietro Angelo Gandolla, Paulo Sergio Cardoso da Silva, Henrique Torquato, and Homero Delboni. 2019. “Long-Term Prediction of Non-Processed Waste Radioactivity of a Niobium Mine in Brazil.” *Journal of Sustainable Mining* 18 (3): 142–49. https://doi.org/10.1016/j.jsm.2019.04.003.
[84]Ibid. Mohammad El Hajj et al.
[85]Ibid. Mohammad El Hajj et al.

Although the Brazilian government works closely with ABNT, outsourcing the regulation of this potentially hazardous material undermines the government's capacity to directly hold firms accountable. Complex regulatory schemes and a lack of direct enforcement capacity in Latin America creates space for malicious actors to operate under conditions with little accountability.

Part IV: Case Studies: Key Strategic Aspects of the REE Industry

There are clear geopolitical and economic motivations to expand the REE sector into new markets, especially given their applications to strategic industries in the defense, green energy, and advanced technology sectors. However, the opaque nature of the global rare earths trade enables profit-focused actors to conduct their operations with little regulatory supervision, increasing the likelihood of potentially exposing local communities and the environment to the industry's negative externalities. Taking these factors into consideration, the following case studies of Brazil and the United States, the largest rare earths markets in the Americas, will serve as the basis for our policy recommendations for Chile. An increased demand with a limited supply of rare earth metals has the potential to exacerbate latent social, economic, and political tensions both locally and internationally. The mining of rare earths begs the question—how can these countries strike a balance between labor rights, environmental protections, and economic growth, and develop effective protective policies?

Brazil's REE Mining Industry

Mining policy has historically been a mechanism through which the Brazilian government has expanded its influence domestically by forging alliances with actors in the private sectors to act on behalf of the interests of the state to assert territorial, political, social, and economic claims within the country's interior. As a country particularly reliant on commodity exports, Brazil's domestic mineral policy has been influenced by the country's relationship with its international trade partners. From the Colonial Era to the late 1800s, Brazil's mining sector had primarily been centered around exporting precious metals like gold and silver. However, as the industrial revolution drastically increased global demand for iron—the base mineral necessary to produce steel—Brazil, with the second largest reserves of this mineral in the world, drastically increased production. It is within this context that Brazil's REE mining sector later emerged as a parallel industry to service the growing demand for global industrial materials. As these international relationships have shifted, Brazil's domestic mineral policy has adapted accordingly to maximize its potential.

As one of the five largest mineral exporters in the world, with more than 3,000 mines[86], the mining sector contributes more than USD 43.7 billion annually to the Brazilian economy or about 2.4% of the country's GDP in 2019[87]. While rare earths like niobium only form a portion of Brazil's overall mining industry, their importance to the global economy as a base metal with applications in the green energy transition, defense industry, and industrial development make them particularly important both economically and geopolitically. This section identifies these particular strengths of Brazil's mining industry:

1. Technology and monopoly in the niobium industry
2. Domestic mineral policy
3. Policy coordination via consolidated mining code/agency

This section identifies these potential areas for improvement:

1. Government favoritism
2. Environmental and social conflicts

Niobium mining has become a particularly important industry within Brazil's mining sector. This is because Brazil has the world's largest reserves of niobium, located proportionally in the states of "Minas Gerais (75.08%), in Araxá and Tapira; Amazonas (21.34%), in São Gabriel da Cachoeira and Presidente Figueiredo and Goiás (3.58%) … the State of Minas Gerais (MG) is the largest producer, with a share of 83.6%, followed by the State of Goiás (GO) with 15.3% and the State of Amazonas (AM) with 1.1%"[88]. Both domestic and foreign firms extract niobium in Brazil. In Goiás, niobium mining is done by CMOC International Brasil, a subsidiary of China Molybdenum. In Minas Gerais, the Brazilian firm CBMM jointly operates the mine with the state government. Combined, these two mines account for 82% of global niobium production[89].

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[86]Ministry of Foreign Affairs of Finland. 2023. "Frontpage." Ministry for Foreign Affairs. 2023. https://um.fi/frontpage.
[87]OECD. 2022. *Regulatory Governance in the Mining Sector in Brazil*. OECD. https://doi.org/10.1787/63d60aa8-en.
[88]Alves, Adilson Rangel, and Aparecido dos Reis Coutinho. 2015. "SciELO - Brazil - The Evolution of the Niobium Production in Brazil The Evolution of the Niobium Production in Brazil." Accessed May 7, 2023. https://www.scielo.br/j/mr/a/BDGSCwPV98xBphJ8vJyrSsk/?lang=en.
[89]Chaves, Léo Ramos. 2019. "The Niobium Controversy." 2019. https://revistapesquisa.fapesp.br/en/the-niobium-controversy-2/.

This near monopoly has significant geopolitical implications for Brazil. For context, "oil analysts point out that Sauid Arabia's position, with 16 percent of reserves and a bit over 10 percent of global production, is so dominant that the country historically has had control over oil prices"[90]. However, "most production concentrations in the rare earth metal sector are far higher and therefore so is their control… In fact, the mine is so critical to the global trading system that the United States places CBMM's Araxá mine on its list of critical infrastructure abroad"[91]. With CBMM's niobium being a critical base mineral for a variety of technical and industrial applications, this mineral has become critical to global trade; a small amount of niobium, when alloyed with steel, can reduce the total steel needed to produce a final end product, making it lighter, stronger, and less expensive overall. For example,"when Gustave Eiffel started constructing the tower that would eventually bear his name, he needed 7,000 tons of steel; today if you wanted to build a replica Eiffel Tower, you would only need 2,000 tons of steel because of CBMM's niobium"[92]. Because of the mineral's unique chemical properties, using a small amount of niobium has a proportionally larger impact in reducing the weight of the alloyed steel without compromising its strength. Niobium, as a result, has become a particularly important component in manufacturing vehicles and aircraft, enabling them to reduce their overall weight and use less fuel as a result. Brazil is not only the world's largest niobium producer, but the magnitude of the nation's unrivaled market dominance and technological applications of the mineral has centered firms like CBMM, and therefore Brazil by extension, in global supply chains.

Technology and Monopoly in the Niobium Industry

A combination of favorable geological and political conditions has enabled Brazil to develop a monopoly over the global niobium trade. For example, as not only the world's largest niobium producer by quantity, but CBMM's methods of extraction are comparatively more cost-effective than other firms because of favorable geological conditions. Benefiting from the economy of sale of its operation, CBMM's mine in Minas Gerais is so large that it is estimated to contain enough niobium to single handedly satisfy global consumption for the next 200 years[93]. As a result, "the company's owner, the Moreira Salles family, has an estimated $27 billion in assets, and around half of which comes from this mine… the mine runs a 37 percent net-income

[90]Op. Cit. Abraham, 40-41.
[91]Ibid. Abraham, 40-41.
[92]Ibid. Abraham, 44.
[93]Ibid. Abraham, 42.

profit margin and earns more than 600 million in profits annually"[94]. Additionally, the mine's soil is relatively loose, so CBMM does not need to rely on expensive explosives to access minerals that are otherwise often found embedded in solid rock. Furthermore, this loose soil means CBMM does not need to use as much energy to extract and grind the raw niobium ore for processing. Finally, CBMM's mine is above ground, making production cheaper than an underground mine requiring designing and managing a costly tunneling system[95]. As the largest niobium producer in the world with some of the lowest operational costs, Brazil's CBMM is a strategic player in the international mineral trade.

Holding a monopoly over the niobium trade has also allowed CBMM, and therefore Brazil, to set the global industry operational standard. Without significant international competition pressuring the global niobium trade to be more transparent, the Brazilian state is relatively lenient in terms of CBMM's reporting standards. This is because it is in the interest of the Brazilian state to craft a regulatory environment which helps to defend the nation's monopoly; an opaque global niobium trade discourages the emergence of new mines outside of Brazil because it is difficult to source accurate market data to make informed investment decisions elsewhere[96]. The Brazilian government and CBMM work in tandem to defend the nation's niobium monopoly because it is in their mutual interest to keep the industry as secretive as possible.

Although other countries have niobium reserves, CBMM's position in the global niobium trade remains largely unchallenged because of Brazil's history of government support for the industry. Typically in the mining industry, investors are looking for a quick return despite the fact that a mine typically takes 10 to 15 years to become fully operational. This has become a particularly salient issue in the rare earths sector because investors interested in financing any given new mining operation prioritize short-term gains over the long-term implications of the project itself. Uniquely, however, because of the company's relationship with the Brazilian state, "CBMM has long-term, deep-pocketed support, the kind rarely found in capital markets today and increasingly only available from governments"[97]. Recognizing both the economic and geopolitical implications of developing a monopoly over the niobium trade, with public sector

[94]Ibid. Abraham, 42.
[95]Ibid. Abraham, 43.
[96]Ibid. Abraham, 65.
[97]Ibid. Abraham, 62.

support, Brazil has created an environment which discourages the emergence of new market challengers elsewhere.

Domestic Mineral Policy

With the state as the ultimate power broker within the mining industry, the strategic geopolitical and economic value of expanding Brazil's rare earths sector to meet rising global demand has superseded certain localized environmental and social concerns. With Brazil's rare earths industry becoming an increasingly important frontier in the rising tensions between China and its rivals, the nation has taken further efforts to increase the competitiveness of its domestic rare earths sector. For example, the National Mining Agency (ANM), the regulatory body for Brazil's mining sector, replaced the DNPM in 2017 "as part of a set of initiatives to review and update the mining regulatory framework, including the promulgation of a new Mining Code"[98]. This new mining code was intended to streamline Brazil's bureaucracy to help solicit investments in the sector more efficiently.

As a result of the nation's internal reforms and rising global demand for rare earths, the United States has included Brazil in its measure to secure critical minerals. For example, in 2020 the Trump administration issues an executive order warning of a "national emergency" because of America's overdependence on "foreign adversaries for the critical minerals that are increasingly necessary to maintain our economic and military strength in the twenty-first century"[99]. A week later, "the new International finance Corporation set up by Trump a year earlier had taken a stake in a mine owned by Techmet in Piauí. Niobium, now on the list of twenty-five critical minerals issued by Trump in an executive order… discussed as the next target for the new US security strategy"[100]. US interests in Brazilian niobium, previously implicit, was formalized under this 2020 policy initiative to officially define and secure critical minerals. Given niobium's utility in the defense sector, the United States has been particularly interested in ensuring it is sourcing niobium from "non-adversarial nations" like Brazil to to minimize the leverage that "adversarial" countries like China may otherwise have over the USA. Recent domestic mineral policy reforms have made Brazil an attractive investment destination for countries seeking to decouple their supply chains from China.

[98]Op. Cit. OECD.
[99]Op. Cit. GOA, 50.
[100]Ibid. GOA, 50.

Policy Coordination via Consolidated Mining Code/Agency

Brazi's contemporary mining code arose as a culmination of a series of historical developments, causing the importance of the mining sector to increase as Brazil's bureaucracy expanded correspondingly to promote and manage the sector. Upon the promulgation of the Estado Novo, under the leadership of Getulio Vargas, "Brazil adopted and implemented import-substitution industrialisation policies, aimed at promoting national industries to reduce the dependency on imports. Brazil developed its mining industry through an active engagement of the State in pursuing a strong entrepreneurial role for itself in the productive sectors of the economy"[101]. As a result of the Vargas administration's statist model of development, Brazil's Mining Code, promulgated in 1934, arose "when progressive forces tried to transform the agrarian economy into an industrial nation. Raw materials and minerals were ingredients of the greatest relevance for the Brazilian State in order to achieve its accelerated economic development goals"[102]. As a result of the establishment of Brazil's first mining code in the Vargas Era, the administration also established the National Department of Mineral Production (DNPM), incorporated within the Ministry of Agriculture, Trade, and Public Works, forming the basis of the nation's current regulatory model as an extension of this statist developmental framework.

Government influence over the extractive sector under this statist model further expanded in 1942; through a joint policy initiative supported by the US government, the Vargas administration created Brazil's first the state-owned mining company Companhia Vale do Rio Doce (CVRD) "using the facilities of the Itabira Iron Ore Company, its railway network, and loans from the American Eximbank"[103]. At the same time, "Vargas created the Companhia Siderúrgica Nacional (CSN). By the late 1940s, CVRD was already responsible for 80 percent of Brazilian iron ore exports. By the 1960s Vale became the most profitable SOE in Brazil and a leader in the world iron ore market"[104]. To manage the growing mining sector, "in 1960, the Ministry of Mines and Energy (MME) was created, absorbing all matters related to mining, and thus, the DNPM was transferred to the MME. Additionally, the Secretariat of Geology, Mining

[101]Op. Cit. OECD.
[102]Machado, Iran F., and Silvia Figueirôa. 2022. "Mining History of Brazil: A Summary." *Mineral Economics* 35 (2): 253–65. https://doi.org/10.1007/s13563-021-00293-0.
[103]OECD. 2014. "Workshop on State-Owned Enterprises in the Development Process." https://www.oecd.org/daf/ca/Workshop_SOEsDevelopmentProcess_Brazil.pdf.
[104]Ibid. OECD.

and Mineral Transformation was established as the unit in charge of dictating the public policies for the mineral sector"[105]. Under this statist model, the mining industry became both vertically and horizontally integrated through a series of state-owned enterprises founded to facilitate Brazil's national development goals. Producing iron at a rate which surpassed Brazil's ability to consume the mineral for its own industrial development, vast quantities of iron were exported to Western countries, namely the United States. In this way, extractive industries and commodity exports became a critical means to achieve internal development; the Brazilian government centered itself in the extractive sector as the main power broker in the country, establishing a precedent of state influence over the extractive sector as a means to pursue Brazil's national interest, forming the basis of the nation's current public-private sector institutional arrangements.

While the foundations of Brazil's contemporary mining policy emerged as a means to achieve the nation's industrialization goals through a statist operational framework, within the context of the Cold War, the Brazilian dictatorship expanded upon this precedent by re-framing development as means to defend against national security risks. A faltering economy was perceived to make Brazil vulnerable to subversive communist influences, and by viewing development through the prism of national defense, expanding the extractive sector forming the basis of Brazil's industrial development became an extension of the nation's national security doctrine. The institutional relationships between the government and the extractive sector corollary expanded in depth and scope. Because of this, "the heyday of state capitalism in Brazil took place in the early 1970s, during the military dictatorship (1964-1985). By 1976-1977, the public sector represented 43% of the total gross capital formation in the country, with around 25% of those investments coming from large SOEs"[106]. Modifying statist import substitution industrialization policies as an extension of Brazil's national security doctrine translated into a period of rapid economic expansion; from 1969 to 1973, Brazil's real GDP rose on average by 11% per year[107]. Although this statist economic model responsible for Brazil's rapid economic growth would also prove to be the source of the dictatorships downfall as it proved to be unsustainable, as the nation's net imports gradually eclipsed the total value of its exports, forcing theregime to double down on this policy by borrowing from abroad and accruing vast

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[105]Op. Cit. OECD.
[106]Ibid. OECD.
[107]Wilkinson, Ross. n.d. "Brazil, Economic Miracle (1968–1974) | Encyclopedia.Com." Accessed May 7, 2023. https://www.encyclopedia.com/humanities/encyclopedias-almanacs-transcripts-and-maps/brazil-economic-miracle-1968-1974.

unserviceable debts eventually contributing to rampant inflation. Centering development as a means to guarantee national security encourages the nation to pursue protectionist policies to safeguard certain firms in the extractive sector deemed critical to Brazil's overall national interest from foreign competition.

With national development becoming inseparable from national defense policy during the dictatorship, porous and sparsely populated border regions were perceived as a national security threat; consolidating control over these regions became tantamount to the military dictatorship's national security doctrine[108]. In the 1960s, the military dictatorship led a geological survey of the Amazon spearheaded by 10 different government agencies to identify and develop the region's mineral resources. Because of both their technological and industrial applications, rare earths became a particular mineral of interest. These dictatorship-led geological discoveries revealed massive unexploited resource potential, discovering that Brazil holds up to 98% of the world's niobium reserves, potentially worth "as much as $22 trillion, more than the entire US GDP and ten times that of Brazil's"[109]. The military government took particular interest in developing these niobium deposits because it can be alloyed with iron to augment the strength of steel, enabling the regime to augment the strength of metals used in industrial applications controlled by state owned firms, like its national airline manufacturer Embraer, or to produce higher quality military equipment. Because of its perceived national security importance and geostrategic location, rather than leaving its exploitation to the private sector in the Amazon, "in 1973, on the estimation that local mineral resources could sustain a regional industrialization project, the Twenty-First Engineering and Construction company of the Brazilian Army relocated to Sao Gabriel da Cachoeira"[110]. Notably, "this relocation occurred contemporaneously with the notorious military assault on Communist guerrillas in Araguaia, which had the effect of refracting the dictatorship's policies through the Cold War prism of dealing with communist threats"[111]. By 1979, the military dictatorship placed the question of mineral exploitation under the jurisdiction of the National Security Council; state-led geological surveys encouraged the development of extractive industries as a means to consolidate control over the contentious

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[108]Wood, Charles H., and Marianne Schmink. 1993. "The Military and the Environment in the Brazilian Amazon." *Journal of Political & Military Sociology* 21 (1): 81–105. https://www.jstor.org/stable/45293936.
[109]Robinson, Andy. 2021. *Gold, Oil, and Avocados*. Melville House, 43.
[110]Klinger, Julie Michelle. 2017. *Rare Earth Frontiers: From Terrestrial Subsoils to Lunar Landscapes*. Cornell University Press. https://www.jstor.org/stable/10.7591/j.ctt1w0dd6d, 184.
[111]Ibid. Klinger, 184.

border region. Prioritizing the immediate perceived threats posed by the Amazon's underdevelopment and control over minerals deemed essential to national security over environmental concerns, mineral exploitation superseded environmental and human rights concerns.

Government Favoritism

Intertwining national development and national security doctrines translated into a hierarchy of privilege in the mining industry based off of an actors' perceived utility to furthering Brazil's national interests. State owned firms, directly controlled by the government, faced fewer bureaucratic and financial constraints when accessing Brazil's mineral resources because the nation's subsoil mineral wealth was already considered to be the property of the state. Because of this, private sector actors were only permitted by the government to extract Brazil's mineral wealth insofar as they demonstrated their utility for advancing Brazil's national interests. In this way, a mutually beneficial and privileged relationship developed between certain mining firms in the private sector and the government. Later privatized, established firms like Vale paid lucrative royalties to the state while simultaneously using their political connections to lobby for favorable legislation discouraging the emergence of new market actors. As we will see in the United States case study, the permitting process can be problematic.

Without political connections in Brazil, for example, "the prohibitively expensive permitting process means that garimpeiros are not conducting mining in a way that allows the state to collect royalties. Second, the clandestine nature of their activities means that they cannot organize investment or other programs to implement environmentally superior technologies"[112]. Small scale actors, such as *garimpeiros*, feared registering their findings and operations with the state, preferring to operate in secrecy albeit with inferior technology, under the assumption that the Brazilian government would grant access to these minerals to established privileged firms. Furthermore, historically marginalized by Brazil's developmental model, Indigenous mining proponents have framed their cause in geopolitical terms, "maintaining that greater control over their local resources would empower them to exert greater control over the Brazilian border while also capturing a greater share of the global rare earth frontier for the benefit of the country"[113]. Small scale mining has the potential to become an important source of economic

[112]Op. Cit. Klinger, 178.
[113]Op. Cit. Klinger, 179.

empowerment for individuals in Brazil's poor and remote border regions. However, developing these resources on their own threatened Brazil's statist economic model by undermining the government's capacity to directly control the mining sector and therefore collect rents. In this way, vested interest within this statist development model meant the government was willing to overlook regulatory infractions causing human rights and environmental violations by large firms while small scale actors were forced to operate in secrecy, preventing oversight all together.

As rare earths grew in importance to the global economy, and therefore became an increasingly important means for Brazil to pursue its national security and development goals, the privileged relationship between the Brazilian government and large scale actors in the niobium mining sector correspondingly increased in scale. For example, using his political and business connections, during the 1960s, the former ambassador and banking mogul Walter Moeria Salles recognized the potential of this burgeoning sector and established a partnership with the US-based rare earths firm Molycorp to produce niobium in Araxá, Minas Gerais in partnership with the Brazilian government.[114] Specifically, "niobium is extracted from the CBMM mine and a pit owned by the Companhia de Desenvolvimento Econômico de Minas Gerais (CODEMIG), a state-owned company. To manage the niobium deposits, in 1972, CBMM and CODEMIG created a joint venture called Companhia Mineradora do Pirochloro de Araxá (COMIPA). The contract between the companies defines the shared control of COMIPA and the equal extraction of ore in mines"[115]. Because Brazil not only holds the largest reserves of the mineral, but also because the government took an early interest in facilitating niobium production in partnership with the private sector, while also investing in research to discover new industrial and military applications for the resource, state support enabled CBMM to develop the first global niobium monopoly, a position which remains largely unchallenged to this day.

As a result of protectionist policies to defend Brazil's global niobium monopoly, since the time when CBMM was founded, from "1965 to 1995 the production increased by about 5 times, and the 10-year period 1995-2005, the increase was about 4.5 times, the last 5 years, between the years 2005 - 2010, the increase in the production of niobium was 1.3 times"[116]. Securing this

[114]Bnamericas. 2019. "At a Glance: Niobium Powerhouse CBMM." https://www.bnamericas.com/en/features/at-a-glance-niobium-powerhouse-cbmm.
[115]Gonçalves, Ricardo Junior de Assis Fernandes, and Bruno Milanez. 2020. "The Territorialization of the Niobium Global Extractive Network in Goiás, Brazil." https://www.ufjf.br/poemas/files/2020/08/Go%C3%A7alves-2020-The-territorialization-of-the-niobium-global-extractive-network-in-Goi%C3%A1s.pdf.
[116]Op. Cit. Alves.

global monopoly was possible because "the Brazilian State acts in a way that contributes to the corporate strategy of the mining companies, making labor and environmental legislation more flexible and being benevolent when holding companies accountable in disaster situations and environmental issues"[117]. Although many SEOs were privatized in the decade following Brazil's return to democracy, the privileged relationship between certain mining firms and the government enabled these companies to expand their operations under a favorable policy environment largely insulated from political volatility associated with the democratic transition and shielded from foreign competition via a protectionist regulatory ecosystem.

This privileged relationship between the public and the private sector is found at all levels of government. For example, in 2009, CBMM financed the construction of a new city hall in Araxá, Minas Gerais, the place where the company's niobium mine is located.[118] Having courted favor with the local government, CBMM later received a relatively lenientant ruling when settling a decades-long environmental lawsuit. Specifically, in 2018 the Minas Gerais state prosecution service and CBMM, "agreed to rectify damage caused by niobium mines dating back to 1982. Then, the process CBMM used to extract niobium from the ore produced a chemical reaction that created barium chloride, a toxic compound that was then dumped in the mine's waste dams"[119]. However, is it also worth noting that "CBMM's rectification agreement was signed less than a month after Minas Gerais state courts dismissed 517 other cases relating to the 1982 contamination"[120]. It is in the interest of the government to not undermine the operations through strict regulatory enforcement mechanisms of large mining firms because of the material benefits they receive from their operations. The government has a vested interest in the success of rare earth mining operations in this way, further enforcing this mutually beneficial relationship at the expense of public accountability. Because of this, state favoritism has enabled certain firms to defend themselves from both foreign and domestic competition while simultaneously establishing a regulatory environment which lacks sufficient accountability mechanisms.

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[117]Op. Cit. Machado.
[118]Diário de Araxá. 2009. "Câmara Municipal conta com apoio da CBMM para a construção da nova sede - Diário de Araxá." June 25, 2009.
https://www.diariodearaxa.com.br/camara-municipal-conta-com-apoio-da-cbmm-para-a-construcao-da-nova-sede/.
[119]Freitas Paes, Caio de. 2019. "Niobium's Silent Impact in Brazil." *Dialogo Chino* (blog). April 5, 2019.
https://dialogochino.net/en/extractive-industries/25588-niobiums-silent-impact-in-brazil/.
[120]Ibid. Freitas Paes.

Domestic Mining an Foreign Investment

Upon democratization, state interests, national security, and mining policy remained intertwined under the previous statist developmental model, but evolved from a series of individual pieces of legislation and decrees into becoming formally codified into Brazil's current constitution in 1988. Upon promulgating Brazil's constitution, mining firms were obligated to restore environmentally damaged areas and "foreign capital was not allowed to represent the majority share in mining ventures…The exploitation of mineral and water resources in Indigenous lands had to be authorized by the Parliament"[121]. Although mineral exploitation was not exclusive to the Amazon, "by overlaying frontier security, mining prohibitions, and the integrity of Indigenous territory, the constitution effectively froze the status quo over the frontier"[122]. In this way, "if the state did not have the immediate capacity to conquer this frontier, then neither could any other extractive interests be permitted, whether Luso-brazilian, Indigenous, or foreign"[123]. Even to this day, in general, foreign investors are not prohibited from acquiring a majority share in Brazilian mining operations. However, "the government interprets the restrictions on non-Brazilian ownership as applying to border areas (i.e., areas within a 150 km-wide strip of land parallel to national borders), as in other countries of the region"[124]. Because of this, "for those companies based in or that have mining assets in a border area, non-Brazilian equity interest is limited to 49 per cent, directly or indirectly"[125]. With significant rare earths reserves located in Brazil's frontier regions, the nation's current constitution and mining code formally entrenched a system privileging extractivist firms which serve the interest of the state to this day.

Within the context of contemporary rising geopolitical tensions similar to that of the Cold War, although now between China and its rivals, the strategic importance of rare earths has caused a return to mining policy as an extension of Brazil's national security doctrine. However, China's current domination over the global rare earths trade has threatened Brazil's niobium niche and its non-alignment foreign policy strategy. This has reinvigorated Brazil's public sector initiatives to augment the capacity of its domestic rare earths industry. For example, in response

[121]Op. Cit. Machado.
[122]Op. Cit. Klinger, 165-166.
[123]Op. Cit. Klinger, 165-166.
[124]Cunha, Pinheiro Neto Advogados-Filipe Morais, and Carlos Vilhena. 2022. "Spotlight: Mining Law in Brazil." Lexology. October 12, 2022. https://www.lexology.com/library/detail.aspx?g=eba38d24-2c1a-41f4-a781-06bfdd8fb515.
[125]Ibid. Cunha.

to the global rare earths supply chain shocks related to the 2010 Japan-China jurisdiction dispute and temporary export ban, Brazil's Mineral Resources Research Company (CPRM), a state owned geological research firm, "jointly with the national department of Mineral Production (DNPM), received the largest federal budget in their history… intended for the public and potential investors and meant to facilitate strategic resource extraction"[126]. Recognizing global interest in diversifying rare earths supply chains away from China, Brazil's legislature also acted in response in 2012 to establish a regulatory code specifically designed to facilitate domestic rare earths mining. In this legislation, rare earths mining is framed as "strategically necessary to Brazil's technological innovation and increased international influence, rare earths are referred to as 'bearers of the futures' (*portadores do futuro*), as crucial to national defense, and as essential to the national sovereign development of Brazil"[127]. In this way, the Brazilian government doubled down on state support of the rare earths sector, centering it within the country's development model and national security doctrine to make Brazil an alternate investment destination for countries seeking to decouple from China.

Because of the 2010 crisis and Brazil's corresponding efforts to pass legislation to increase foreign engagement in the nation's rare earths sector, global geopolitical tensions have manifested domestically within certain mining firms. These efforts proved to be fruitful, because seeking alternative rare earths sourcing destinations to insulate themselves from China's leverage over the global trade, Korean and Japanese companies, "some of CBMM's biggest customers, bought a combined 15 percent stake in the firm in March 2011 for $1.8 billion, with support from their governments. China followed suit, acquiring a 15 percent share six months later for $1.95 billion"[128]. However, to ensure this new foreign investment did not undermine Brazil's control over its domestic rare earths sector, "the Asian minority shareholders were forbidden to carry out technical due diligence research"[129]. With CBMM lucratively centered between rival factions, Brazil's niobium has become "a key element in lithium-ion batteries used to power electric cars. CBMM and the Japanese auto company Toshiba are working to develop a niobium-titanium oxide anode that cuts the charge time for an electric-car battery in half. China dominates the

[126]Op. Cit. Klinger, 165-166.
[127]Op. Cit. Klinger, 165-166.
[128]Op. Cit. Abraham, 42.
[129]Op. Cit. Abraham, 42.

global lithium battery market"[130]. As mentioned in Part 3, Japan's critical mineral policy is framed as a means to secure rare earths essential for its economically important technology manufacturing sector. While Japan and China compete geopolitically in Asia, this political rivalry has manifested economically within the ownership structure of CBMM, seeking to offset the influence of the other within the global niobium trade. Strategically CBMM, and Brazil by proxy, also continues to engage with China in this sector as well, stoking supply chain control anxieties between rival factions by using their mutual paranoia to continuously solicit greater degrees of investment to counter that of the other.

This multi-party minority ownership structure, however, further reinforced Brazil's dependence on international niobium trade relationships. Specifically, for example, favorable policy initiative oriented towards China's internal market produced positive externalities for CBMM, and by extension Brazil, given the countries' mutual dependence in the niobium sector. Later, for example, to further secure its place within Brazil's domestic niobium sector, "in 2016, the Chinese company China Molybdenum Co. Ltd. acquired two nearby mines, representing 10% of global niobium production"[131]. With a greater portion of Brazil's niobium supply under the influence of Chinese government, later "partly because of a change in Chinese regulations requiring builders to use stronger steel girders, sales of ferro-niobium ingots — one of CBMM's most popular products—surged by 26 percent in 2018"[132]. Government initiatives to strategically center Brazilian firms like CBMM in this global struggle for critical mineral reserves encouraged adversarial countries to compete for the nation's resources in a controlled environment, to the mutual benefit of the nation's public and private sector. This, however, has further reinforcing the mutual dependence between large mining firms and the state. Firms like CBMM rely on the state to craft a carefully balanced policy environment liberal enough to encourage foreign investment but sufficiently protectionist to shield them from foreign competition in their domestic extractive operations. The state has a vested interest in the continuous growth of large scale mining operations like CBMM as a means to increase its global power projection by strategically centering itself as a neutral investment destination between rival factions.

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[130]Lockwood, Devi, and Leo Schwartz. 2020. "Niobium: The Mighty Element You've Never Heard of." Rest of World. November 25, 2020. https://restofworld.org/2020/niobium-the-mighty-element-youve-never-heard-of/.
[131]Ibid. Lockwood.
[132]Lapper, Richard. 2019. "Bolsonaro Took Aim at China. Then Reality Struck." 2019. https://www.americasquarterly.org/article/bolsonaro-took-aim-at-china-then-reality-struck/.

Balancing the interest of adversarial countries has led CBMM to develop a multifaceted operational strategy as concerns surrounding rare earths revolve around their applications for the defense industry, technology production, and green energy applications as well. While China's concerns in Brazil's rare earths sector are limited to its geostrategic implications, CBMM has further carved out its niche in the niobium trade by casting itself as not only as a safe hedge against global supply chain vulnerabilities, but also as a uniquely environmentally friendly sourcing option as well. In 2012, CBMM "invested US$430 million to expand production facilities to produce three thousand tonnes of rare earth oxides annually".[133] Later "in 2013, the company invested another US$24.7 million to double the capacity of rare earth production"[134]. Importantly, "the plant uses recycled water from mining operations to produce rare earth oxides in a way that reduces their overall waste footprint, and operates under the most stringent international industry standards for environmental and occupational health safety in a region that is not considered environmentally sensitive"[135]. However, it is important to note that these sustainable initiatives developed only recently and arose as a means to secure foreign investment and to placate local social and environmental concerns. As international companies have fallen under increased scrutiny for sourcing their rare earths from firms responsible for environmental degradation, CBMM has attempted to secure its business partnerships globally by defining itself in opposition to environmentally damaging extractive methods common elsewhere.

Environmental and Social Conflicts

Despite CBMM's massive investments in developing environmentally friendly rare earths facilities, these initiatives have done little to attract new investments in themselves. Rather, price and geopolitical factors remain the primary concern of market actors seeking to engage with Brazil. Specifically, without major technological or regulatory hurdles, the "remaining challenge for CBMM was to find downstream buyers willing to pay a premium for sustainably produced, non-Chinese source of rare earth oxides. Industry analysts explained the failure of the sustainable rare earth initiative strictly in terms of price competition: if CBMM could beat China's price, then they would dominate the global market"[136]. Although CBMM, and therefore Brazil by

[133]Op. Cit. Klinger, 161.
[134] Ibid. Klinger, 161.
[135] Ibid. Klinger, 161.
[136] Ibid. Klinger, 168.

proxy, outperforms China in terms of the scale of its niobium production, China's limited presence in the global niobium trade remains a threat to Brazil's domestic industry because China can produce the mineral at a lower price. While efforts to make CBMM's more sustainable were successful, it failed to achieve the desired result of capturing the remaining, albeit comparatively miniscule, portions of the global niobium trade controlled by China.

Although rare earths firms like CBMM have made efforts to mitigate their negative environmental and social externalities to attract foreign investment, other actors in the mining sector have escalated environmental and social conflicts. However, CBMM still controls nearly 80% of global niobium exports, meaning the industry itself is largely sustainable. Although recent efforts to expand Brazil's overall niobium production have been carried out in such a way that damages the environment. This has undermined Brazil's overall reputation as an environmentally friendly and socially responsible investment destination as CBMM's model has proven to be an exception rather than the norm. For example, seeking to expand upon the success of Brazil's initial 2012 mining code revision encouraging foreign investment in the nation's domestic rare earths sector, the nation undertook further regulatory reforms inspired by geopolitical factors to further exploit Brazil's mineral resources. For example, eclipsing the position of the United States in the same period, "China was now Brazil's number one trading partner and destination for 35 percent of its exports"[137]. After president Dilma Rousseff was impeached and replaced by the right-wing Temer administration, threatened by implications surrounding the increasing Chinese influence in Brazil, "Washington foreign-policy hawks set out to reestablish the anti-communist Washington-Brasília axis"[138]. With a growing number of conservatives in Brazil's Congress similarly concerned with the disproportionate Chinese influence over the nation, such as senator and governor of Roraima Romero Jucá, a leading figure in the Rousseff impeachment proceedings, the Brazilian state took an active role in facilitating the expansion of the nation's mining sector by opening up federally protected land for mineral exploration. National security and economic concerns have converged between Brazil and the United States within the context of rising geopolitical tensions with China, encouraging domestic actors to expand extractive activities on otherwise federally protected land.

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[137]Op. Cit. Robinson, 44.
[138] Op. Cit. GOA, 45.

Under a favorable policy environment, relationships between the Brazilian mining interest and the state became further entrenched as favorable institutional arrangements became subject to a greater degree of direct influence. For example, senator and governor Jucá's daughter, heavily involved in the niobium mining industry, "was a leading partner in the Boa Vista mining company, had spent years trying to legislate mining access to Indigenous lands"[139]. Temer himself was previously president of the National Indian Foundation (FUNAI), a government agency designed to oversee the management of Indigenous land, but with allies in Congress, "Jucá had used the post to encourage garimpeiro gold miners and loggers to seek their fortunes in the millennial territory of the twenty-five thousand Yanomami who inhabited the dense forests in northwest Roraima where niobium and other critical minerals are also present"[140]. Within Brazil's evolving geopolitical context, mineral exploitation remained a means to pursue national development and security goals, however perceived barriers to Brazil's policy goals shifted and expanded in scope. During Brazil's dictatorship era, national security threats were perceived to originate from internal subversive communist influences taking advantage of Brazil's underdevelopment. However, within the context of rising global geopolitical tensions, certain actors perceived that Brazil's economic position in the world, and therefore its ability to guarantee its own national security, was being undermined by Indigenous peoples' presence on federally protected land. Increased demand for critical minerals, such as niobium, has correspondingly escalated efforts to exploit new mineral frontiers, and therefore, undermine constitutionally protected Indigenous and environmental rights.

After the 2017 mining code revisions, not only were large firms like Boa Vista better able to exploit new mining frontiers, but the scale of artisanal mining grew and the industry's overall export value increased as well during and after the 2016-2018 Temer administration as seen in Figures 4.1 and 4.2 below.

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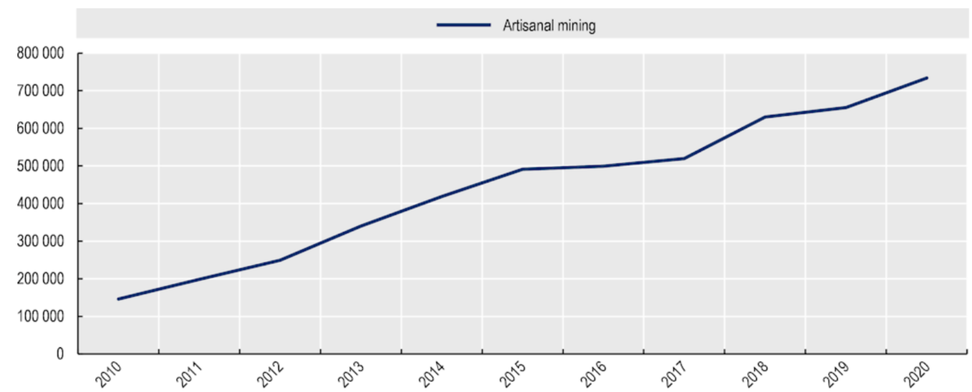
[139]Op. Cit. GOA, 45.
[140]Ibid. GOA, 45.

Figure 2.3. **Land area devoted to artisanal mining**

Area in hectares



Notes: The data referred to 2020 are still preliminary. Land areas refer to active processes in the Mining Cadastre System (*Sistema Cadastro Mineiro,* SCA).

Source: ANM (2021[8]), *Cadastro Mineiro*, Portal Brasileiro de Dados Abertos, https://dados.gov.br/dataset/sistema-de-cadastro-mineiro (accessed 16 July 2021).

Figure 4.1. Land area devoted to artisanal mining[141]. Source: OECD.

Figure 2.10. **Mining imports and exports as share of Brazil's GDP, 2010-19**

Source: Ministério da Economia (2020[25]), *Comex Stat*, http://comexstat.mdic.gov.br/pt/home.

Figure 4.2. Mining imports and exports as share of Brazil's GDP, 2010-2019[142]. Source: OECD.

This trend has continued, becoming especially controversial as both formal and informal mining operations have taken an increased interest in mining on protected land since the 2017 reforms, threatening to inflame social and environmental conflicts further, particularly escalating in 2018 as seen in Figure 4.3 below.

[141]Op. Cit. OECD.
[142]Ibid. OECD.

Requests for authorization to mine on indigenous lands in the Amazon

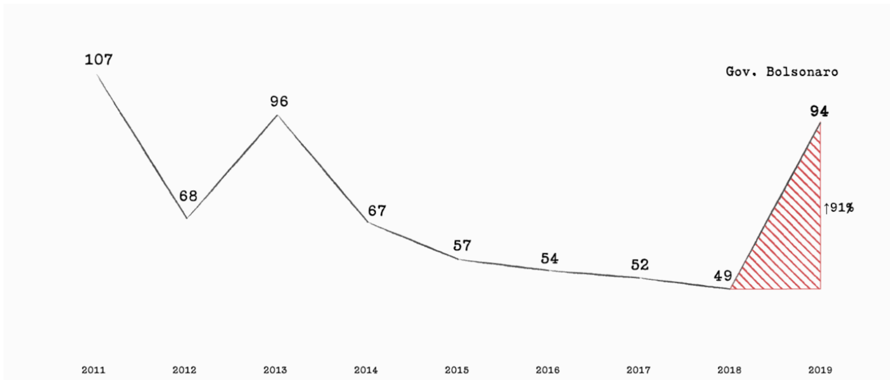


Figure 4.3. Requests for authorization to mine on Indigenous lands in the Amazon[143]*. Source: Mongabay.*

As China eclipsed the USA as Brazil's largest trade partner, an unbalanced trade relationship threatened Brazil's foreign policy strategy of centering itself as a commodity exporter between adversarial countries, becoming correspondingly overexposed to Chinese influence. This "same paranoia would drive Bolsonaro's policies on niobium and other critical minerals. In order to avoid the seizure of Roraima's underground wealth by the Chinese, it was necessary to open concessions and give preference to Brazilian mining concerns or, failing that, to the extractivists of the world"[144]. In this way, "although the international community tends to see mining and rainforest conservation as diametrically opposed, among domestic stakeholders, including a diverse set of Indigenous activists, the question of mining… is not framed in terms of whether it should occur, but rather by whom and under what political economic conditions"[145]. Because the mining industry had become a means to an end to guarantee the nation's national security, this trade imbalance in the mining sector became framed as an existential crisis for the nation rather than exclusively an economic risk.

The United States' REE Mining Industry

Given the strategic implications of the global REE trade, within the last decade, the United States has made securing access to these critical minerals a policy priority. As discussed

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[143]Agência Pública. 2020. "The Mining Map: Who's Eyeing the Gold on Brazil's Indigenous Lands?" Mongabay Environmental News. May 7, 2020. https://news.mongabay.com/2020/05/the-mining-map-whos-eyeing-the-gold-on-brazils-indigenous-lands/.
[144]Op. Cit. GOA, 51.
[145] Ibid. Klinger, 168.

in Part III, in order to secure access to these critical minerals, the United States has undertaken policy efforts to encourage REE production both domestically and within friendly nations as well. However, the country has struggled to translate abstract policy initiatives into tangible action. The growing prominence of rare earths in the energy industry has led, over the past few years, to several countries to independently increase their production capacity in an attempt to partially capture China's dominant market share in the global REE trade. Although some progress has been made, tepid results from these initiatives have caused the government of the United States to further heightened the importance of rare earth elements by declaring their control – and the current market monopoly by China – a national security threat[146]. While the implications of China's leverage over the base minerals necessary for the defense industry, green energy transition, and advanced technology production are an economic concern, the USA in particular has framed discourse surrounding alternative rare earth supply chains in terms of national security given that the country's defense sector heavily relies on materials sourced from China. Because of this, while recognizing its own limitations, the United States has prioritized increasing domestic production of rare earths while secondarily seeking alternative sourcing partners in friendly nations to offset the USA's overall reliance on China in this strategic sector.

Despite the United State's vast rare earths resources, establishing new mining operations has proved to be costly and contentious. The United States holds an estimated 3.6 million tons of rare earths resources; importantly, these are also dispersed throughout the county in such a way that they are often found in economically viable concentrations for extraction[147]. Balancing conflicting interests of various stakeholders, however, has become a particularly salient factor limiting the expansion of domestic REE mining operations in the USA. For example, since the radioactive spill in the Navajo Nation in 1979, the United States has drastically increased legislation to protect the environment. Because of this, the country's comparatively robust environmental regulations serves as a tangible accountability mechanism which helps mining firms to secure the social license to operate by providing local communities legal recourse against any perceived infractions. However, these stringent regulations in themselves are insufficient to fully compensate for the negative perceptions local communities hold towards extractive industries overall. As a result, the prospect of new mining operations is frequently met

[146]Op. Cit. Zhang, 2022.
[147]USGS. 2023. "Mineral Commodities Summaries 2023." 2023. https://www.usgs.gov/.

with fierce community-led resistance, especially in areas like the Navajo Nation whose environmental concerns are compounded by questions surrounding the sovereignty of Indigenous territory.

Like other countries, however, the USA's mining sector has strengths and weaknesses. This section identifies the following strengths of the US REE industry:

1. Evolving legislation and rigorous permitting process
2. Federal support including grant/loan money/tax incentives

Our analyses of the United States also uncovered several potential areas for improvement:

1. Discouraging length of the permitting process
2. Lack of cohesion between government agencies
3. Priority on imports

Evolving Legislation

A major strength of the USA's REE mining sector stems from the country's steadily evolving policy environment which adapts to meet the macro-level needs of the country. Because domestic mining policy is often informed by the country's international relationships, deteriorating relations between the United States and China has correspondingly translated into a series of bipartisan initiatives to secure critical mineral resources, placing a particular emphasis on rare earths. Because of this, the estimated value of rare earths compounds and metals imported by the United States in 2022 was $200 million, a 25% increase from $160 million in 2021[148]. Despite this net growth of imports and interest in diversifying supply chains, the US Geological Survey (2023) reports that the United States imported REEs from: China, 74%; Malaysia, 8%; Estonia and Japan, 5% each; and 8% from others. Although the country recognizes the strategic risks associated with its overreliance on Chinese imports, in the short-term, the USA has continued to engage with China in this sector to stockpile rare earths until alternate sourcing destinations become viable.

In the meantime, to offset this reliance on Chinese imports, the United States has also increased domestic production of rare earths; the 2023 Mineral Commodity Summary for Rare

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[148]Ibid. USGS.

Earths identified significant underexploited reserves of bastnaesite (a mineral composed of the rare earth elements cerium, lanthanum, and yttrium) at Mountain Pass, the USA's only operational rare earths mine, which is located in the Mojave Desert of California. Another mineral, monazite (composed of cerium, lanthanum, neodymium, and thorium) exists in economically viable concentrations in the southeastern United States. Recent interest in exploiting these reserves has caused the USA's domestic rare earths production to grow from a value totaling $160 to $200 million between 2021 and 2023 respectively, a 25% increase. Although the increased rare earths imports and domestic production has the potential to eventually offset the USA's reliance on China, the United States remains vulnerable to China's strategic leverage over this sector.

Despite its strategic national security implications, the USA's defense sector's size and economic impact are proportionally smaller in scale than the green energy and advanced technology sectors. As a result, in the USA, catalysts remain the leading domestic end-use of rare earths, a critical component to produce electric vehicle batteries. Although raw rare earths ore serves little purpose until it is refined, the United State's refining capacity remains similarly limited. There is a corresponding refining facility at the Mountain Pass mine and another operation called Round Top Heavy Rare Earth, Lithium and Critical Minerals Project in Hudspeth County, Texas. Due to the contentious nature of the industry, these refining operations are located far from major population centers in the USA. Because of the distinct regulatory environment in the USA as a result of its federal system, recent interest in establishing new refining operations often manifests in jurisdictions with comparatively lower regulatory burdens. However, the scale of these existing and potentially new operations are not large enough to fully satisfy the refining needs of the USA. As a result, the US government, declared the Energy Resource Governance Initiative (ERGI) initiative (2019), led by the US State Department, with the goal of increasing rare earths production outside the nation as "increasing demand for renewable energy, electric vehicles, and battery storage technologies will create unprecedented demand for energy resource minerals"[149]. In this way, the United States government has sought to both facilitate the development of its own domestic rare earths industry while seeking additional sourcing destinations to supply additional minerals to satisfy the remaining internal demand.

[149]Bureau of Energy Resources. 2019. "Energy Resource Governance Initiative (ERGI)." https://www.state.gov/wp-content/uploads/2019/06/Energy-Resource-Governance-Initiative-ERGI-Fact-Sheet.pdf

The United States government has since passed legislation to facilitate the development of its domestic REE mining and refining industries while correspondingly implementing regulatory stipulations to manage the negative externalities an expanded rare earths sector may otherwise pose to the environment and local communities. The historical basis of the USA's contemporary rare earths mining regulatory framework evolved from the Mineral Leasing Act of 1920, which requires that a royalty be paid on amounts mined and sold when leased from public lands including oil, gas, coal and other non-energy leasable minerals — followed by the Materials Act of 1947, which provides for the disposal of mining materials on public lands[150]. REE mining, among other industries, is impacted greatly by the Clean Water Act (CWA) enacted in 1948 but updated in 1972, which made it unlawful to discharge any pollutant from a point source into navigable waters, unless a permit was obtained[151]. The CWA, in the modern day, is enforced through compliance monitoring, regulated through the EPA along with federal, state, and local governments.

Although the country held the first monopoly over the industry, REEs were not mentioned in United States mining legislation until the twenty-first century. The American Mineral Security Act (S. 1317) was first introduced to the Senate in 2019, with objectives of: providing statutory authority for the US Geological Survey to designate and update every three years a list of critical minerals; requiring a comprehensive national assessment of every critical mineral; and provides for a study to design an interdisciplinary program on critical minerals that will support the critical mineral supply chain and increase domestic critical mineral development, amongst others[152]. As securing stable rare earths supply chains has become a point of national concern, the US government has correspondingly adapted its legislation and regulatory environment in an attempt to guarantee access to these strategic minerals while managing their environmental impacts.

Within the past few years, these efforts have intensified. As the country's trade relationships have become more globalized, but as China's position within the global economy has posed a greater threat to the USA's national security, the increasing importance of securing

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150 US Bureau of Land Management. n.d. "Programs: Energy: Mining and Minerals: About Mining and Minerals | Bureau of Land Management." Accessed April 20, 2023. https://www.blm.gov/programs/energy-and-minerals/mining-and-minerals/about.

151 US EPA, OP. 2013. "Summary of the Clean Water Act." Overviews and Factsheets. February 22, 2013. https://www.epa.gov/laws-regulations/summary-clean-water-act.

152 Sen. Murkowski, Lisa [R-AK. 2019. "S.1317 - 116th Congress (2019-2020): American Mineral Security Act." Legislation. 10/22/2019. October 22, 2019. http://www.congress.gov/.

rare earths resources has caused mineral policies previously compartmentalized within their respective agencies or branch of government to become more streamlined and complimentary. In this way, mineral and environmental regulatory agencies under the executive branch have become an integral part of the USA's national security doctrine, and the country's legislature has correspondingly become an important source of regulatory accountability. For example, in the Executive Branch, the State Department's 2019 Energy Resource Governance Initiative (ERGI) has three main goals. First, to engage with resource rich countries on responsible energy minerals governance. Second, to support resilient supply chains, and third, to meet the expected demand for clean energy technologies[153]. As goals of this project, the initiative focuses on sharing best practices on minerals management and transparent markets, promoting sustainable mining practices, integrating resilient supply chains, and facilitating new research and development, among others. In this way, the State Department has developed a regulatory capacity outside of its typical scope of operations as a means to further the United State's foreign policy agenda.

Similarly in 2022, within the the US Legislative Branch, the Restoring Essential Energy and Security Holdings Onshore for Rare Earths Act of 2022 (REEShore Act of 2022, or S.3530) was introduced to encourage the extraction and processing of rare earths in the United States to undermine China's leverage over global supply chains. Although this act has not yet been voted upon, it includes the following objectives: strategic rare earth metal and rare earth metal products reserve; requires any contractor providing to the Department of Defense disclose the provenance of its origin; restricts the use of Chinese-made REEs in military technologies; investigates unfair trade practices; and encourages allied countries to "eliminate their dependence on non-allied countries for rare earth metals to the maximum extent practicable" and "assessing initiatives in other countries to increase rare earth metals production capabilities"[154]. Through this bill, actors in the US Legislative Branch are pursuing domestic initiative with foreign policy implications as a means to influence the Department of Defense under the jurisdiction of the Executive Branch.

Furthermore, in 2022, the Department of Interior (DOI) announced the establishment of an Interagency Working Group (IWG) that will "lead an Administration effort on legislative and regulatory reform of mine permitting and oversight"[155]. Some of the fundamental principles for

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[153]Energy Resource Governance Initiative (ERGI), 2019.
[154]Sen. Cotton, Tom [R-AR. 2022. "Text - S.3530 - 117th Congress (2021-2022): REEShore Act of 2022." Legislation. 01/20/2022. January 20, 2022. http://www.congress.gov/.
[155]House, The White. 2022. "FACT SHEET: Securing a Made in America Supply Chain for Critical Minerals." The White House. February 22, 2022.

mining reform include the promotion of responsible mining under strong social, environmental, and labor standards[156]. Contemporaneously, the United States Congress created the Critical Minerals Caucus, a bi-partisan group who develop policy initiatives regarding this issue. This caucus intends to change tax incentive structures to make production in the US more attractive than other countries.

The domestic REE industry in the US is growing according to federal and geopolitical initiatives. Technology advances faster than mines can open, and therefore there is a disconnect between supply and demand for rare earths both domestically and internationally. REE mines can take up to fifteen years from investment to production according to the US government due to a large amount of technological foresight of mining companies and an increased concern in the environmental impacts of the industry[157]. In California, the Mountain Pass mining site was taken over by new owners in 2017. However, the excess REEs not refined domestically are still sent to China for processing. Because multiple agencies and government branches alike have taken an increased concern over the USA's overreliance on China, in 2020, the US Department of Defense "approved funding a joint venture between the Australian firm Lynas Corporation and the US firm Blue Line Corporation" to build a processing plant in Texas. This processing plant — known as USA Rare Earths — has yet to begin production. If successful, this processing facility would be able to process REEs mined domestically and imported from other countries, including Australia and Japan"[158]. The USA Rare Earths major venture would become an extension of the Round Top Heavy Rare Earth, Lithium, and Critical Minerals Project in Texas to augment the aggregate production and refining capacity of the United States. This project is notable for its relative affordability and sustainability, potentially becoming the lowest-cost rare earth and lithium producers in the world. Their business model claims to be "producing materials for clean, green, renewable applications, using a process that employs clean, green, renewable power — without harming the environment or surrounding communities"[159]. Once recommissioned, this plant will be "the only sintered neo-magnet manufacturing facility in the Americas"[160]. USA

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https://www.whitehouse.gov/briefing-room/statements-releases/2022/02/22/fact-sheet-securing-a-made-in-america-supply-chain-for-critical-minerals/.

[156]Biden-Harris Administration Fundamental Principles for Domestic Mining Reform. February 22, 2022

[157]Op. Cit. Abraham, 49-50.

[158]Op. Cit. Jorge-Ricart.

[159]USARE. 2021. "USA Rare Earth to Produce Nearly Half of New U.S. Government Critical Minerals List." USARE. December 13, 2021. https://www.usare.com/post/usa-rare-earth-to-produce-nearly-half-of-new-u-s-government-critical-minerals-list.

[160]Ibid. USARE.

Rare Earth's complimentary mine contains the largest gallium deposit in the United States and will be the only US producer of the gallium semiconductor chips; on a smaller scale, it will also produce neodymium, dysprosium, praseodymium, and terbium[161]. Recognizing the strategic importance of securing a reliable supply of rare earths, multiple agencies and government branches have come together to facilitate the development of projects in the private sector like USA Rare Earths while simultaneously ensuring this uptick in production does not result in burdensome negative externalities impacting the environment or local communities surrounding these operations.

Federal Support and Incentives

The US government has further demonstrated its commitment to developing rare earths supply chains away from China by not just passing favorable legislation and regulations, but by also taking an active role in providing grants, loans, and tax incentives to make the industry more attractive to new actors in the private sector. Given their similar technological applications, the White House has defined rare earths, as well as lithium and cobalt, as critical minerals. As stated, the United States government declared the reliance on 'adversarial countries' as suppliers of critical minerals poses a national and economic security threat. As such, the Biden administration has called for an increase in working with partner organizations and allied countries to diversify sustainable resources. The report recommends that the United States increase domestic mining, production, processing, and recycling of critical minerals, with an emphasis on "strong labor, environmental and environmental justice, community engagement, and Tribal consultation standards"[162]. As of 2022, the Biden administration has also prioritized updating mining laws and regulations. The majority of mining of critical minerals is legislated by the Mining Law of 1872 — over 150 years old. This law declares that all valuable mineral deposits in land belonging to the United States is free and open to exploration, giving citizens the right to "explore for, discover, and purchase certain valuable mineral deposits on federal lands that are open for mining location and patent (open to mineral entry)"[163]. Building upon the legislative precedent, the United States government has invested heavily in the development of the REE industry: President Biden announced that the Department of Defense's Industrial Base Analysis and

[161]Ibid. USARE.
[162]Op. Cit. The White House.
[163]Op. Cit. Bureau of Land Management.

Sustainment Program awarded $35 million to augment the capacity of the Mountain Pass facility to separate and process REEs as a means to establish a full domestic permanent magnet supply chain, with the intention to invest another $700 million by 2024[164].

Furthermore, the Biden administration also announced in 2022 that the Department of Energy planned to allocate more than $2.8 billion in grants from the Bipartisan Infrastructure Law to twenty domestic manufacturing and processing facilities under the American Battery Materials Initiative to further stimulate the USA's incipient domestic REE industry. Overall, the Bipartisan Infrastructure Law has pledged to invest more than $7 billion in domestic production of critical minerals[165]. Additionally, instead of exclusively focusing on just the production of rare earths, the Biden-Harris administration's bipartisan CHIPS & Science Act of 2022 serves as a complimentary legislative initiative to reinvigorate the USA's domestic advanced technology manufacturing sector by offering incentives for investment in research, the of development, science and technology, among other goals[166]. Combined, the Bipartisan Infrastructure Law and the CHIPS & Science Act serve as part of the US goal to secure domestic supply chains for critical minerals.

The Inflation Reduction Act (IRA) further compliments these two legislative initiatives by offering incentives in the form of tax credits which support using mineral and battery components processed domestically or for firms sourcing raw materials from friendly countries with free trade agreements with the USA like Chile. Specifically, these credits are intended to help domestic manufacturers "retool existing facilities and build new battery manufacturing and critical mineral processing in the United States as well as grants to deploy zero emission heavy-duty vehicles"[167]. The Federal Government further provided more than $200 million through the Department of Defense towards securing rare earth supply chains, investing in scientific innovation and launched a mining reform effort to ensure new these initiatives meet strong environmental, community, and Indigenous engagement standards[168]. Critically, while the USA ultimately wants to be self-sufficient in the rare earths sector, the country recognizes its own limitations. As a result, these rare earths initiatives have not been crafted to create a new-USA global monopoly in the sector; rather, because diverging supply chains away from

[164]Ibid. Bureau of Land Management.
[165]Op. Cit. The White House.
[166]Ibid. The White House.
[167]Ibid. The White House.
[168]Ibid. The White House.

China is the policy priority, the USA has become interested in both increasing its own domestic production while simultaneously seeking alternate trade partners to supplement the USA's consumption of critical minerals. In this way, securing rare earths has not just become a domestic policy priority, but under the CHIPS Act and the IRA, doing so has also caused the USA to take interest in sourcing rare earths from new trade partners as well.

Discouraging Permitting Process

As the USA's policy environment facilitating and regulating the extractive sector has become more complex, so too has the permitting process to open new mines. Although various administrations have expanded or reduced certain regulatory requirements, choosing to prioritize the wellbeing of local stakeholders or the macro-economic implications of the extractive sector, overall mining companies face significant bureaucratic hurdles. For example, under the Trump administration, climate change and environmental concerns did not rank highly on the Federal Government's agenda. Later, the Biden administration set a target for reducing greenhouse emissions exponentially by 2030 and industry standards on environmental protection are at all-time highs. However, the need to drastically reduce reliance on fossil fuels and promote greener forms of energy production mean that these new 'cleaner' industries requiring significant amounts of rare earths must grow rapidly over the next ten years.

As in Brazil, the permitting process can be prohibitive. One major concern on the successful implementation of net-zero carbon emissions are the bureaucratic hurdles associated with the permitting process, which currently can take up to sixteen years from initially applying to becoming operational. The multi-layered permitting process for extractive operations depends on the size, geography, technology, and jurisdiction of the project but typically require approval from local, state, and federal authorities[169]. On the local level, companies require land-use permits based on the zoning and planning ordinances of their jurisdictions, and often require informed consent of the communities in and around the area of operation. On the state level, projects must adhere to twenty environmental review laws, which mandate studies of the environmental effects of the project among others. Projects which cross state lines are also subject to interstate and regional transmission networks, which are usually part of a "queue"

[169]Patnaik, Rayan Sud and Sanjay. 2022. "How Does Permitting for Clean Energy Infrastructure Work?" *Brookings* (blog). September 28, 2022. https://www.brookings.edu/research/how-does-permitting-for-clean-energy-infrastructure-work/.

system where cases are viewed sequentially and can take years to pass. Finally, large projects may require additional Federal Government permits related to wildlife protection, endangered species consultation while also demonstrating compliance with the Clean Air Act, the Clean Water Act, protected land use requirements, construction and operations plans, and more[170]. Although the regulations stipulated by the permitting process are critical to managing the negative externalities of the mining sector, and therefore helping to secure the social license to operate, the way in which these measures are operationalized, with lengthy processing time and bureaucratic redundancies, slows the rate at which new mining projects can become operational. This is a particularly salient issue because the efficacy of USA's critical mineral policy is contingent upon the speed at which the country can make new mines operational, a potential liability should China choose to once again assert its leverage over global supply chains and "weaponize" rare earth exports.

Notably, the permitting process can halt progress at any point; the larger the size of the project, the more evaluations are required. For large projects, the National Environmental Policy Act (NEPA) can halt these operations through procedural law after assessing the potential environmental impacts[171]. Projects of a certain size must also submit an Environmental Impact Statement (EIS) which allows for input by the local communities and interest groups who may be affected by the project. Without a streamlined procedure, the current byzantine permitting process stunts many projects before they can pass the preliminary phases of operation. While the regulations themselves are critical to ensuring the safety and sustainability of the mining operation, the lengthy and costly bureaucratic compliance process is a factor deterring the development of domestic rare earths operations. Bipartisan officials have spoken out on the issues of the permitting process, particularly as the backlog created by the current processes stalls projects that are in extreme need which may otherwise be in compliance with environmental standards.

In this way, developing mechanisms to comply with the USA regulatory framework is less burdensome than the process required to prove compliance. For example, just 21% of planned wind turbine projects in 2021 passed through the permitting process into the construction phase[172]. Although some of these projects may have failed to meet one of the

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[170]Ibid. Patnaik.
[171]Ibid. Patnaik.
[172]Ibid. Patnaik.

regulations, many more have not yet been considered and are in limbo within the permitting process. The local level can be the slowest in the process as lack of capacity can cause the queue of permits to slow down greatly. This lack of vertical bureaucratic cohesion means that projects to increase the USA's domestic rare earths production, which ultimately form the base of green energy projects like wind turbines, negatively impacts the rate at which the country can pursue its critical mineral policy agenda to facilitate the USA's green energy transition. Because of this, overly complex bureaucratic barriers designed to protect the local environment have the unintended consequence of limiting the USA's ability to implement green technology solutions to fight climate change.

Advocates for this system believe that the lengthy process is a necessary 'due diligence' process for guaranteeing high industry standards to protect the environment. However, the fact that most delays in permitting come from a procedural lack of capacity or inconsistencies between government agencies than actual permitting issues themselves[173]. Furthermore, the lengthy processes come at a cost: permits for extracting and processing within the United States can discourage investors from taking advantage of domestic industry. As such, domestic manufacturers often choose to outsource the procurement of raw materials otherwise compliant with US regulations from jurisdictions with less stringent regulations like China, forcing domestic firms to double down on their reliance on potentially geopolitically vulnerable supply chains. Recognizing this, The Biden administration launched a Permitting Action Plan to strengthen and accelerate the permitting process[174]. However, given the discrepancy between a mine's initial application to secure regulatory approval and date at which it becomes operational, the impacts of Biden's Permitting Action Plan initiative have yet to be seen. As a result, for the REE industry, the length of the permitting process—at least relating to the queue sequential nature of the submission process and associated delays—could stall initiatives to increase the USA's domestic REE production.

Although extractive industries are notorious for their impact on the local environment, their negative externalities can be managed with sufficient government oversight. Like in Brazil, the rare earths industry has been identified by policy makers in the USA as geopolitically and economically strategic, inspiring them to pass legislation to further develop the industry;

[173]Ibid. Patnaik.
[174]Op. Cit. The White House.

however, the USA proves that with sufficient government support, new rare earths operations can become economically viable under a robust environmental regulatory framework without having to sacrifice profit. Multiple different agencies within the US government currently claim jurisdiction over REE production: the Department of Energy (DOE), the Department of Defense (DOD), and the Department of Commerce (DOC). Although the strategic implications of the USA's overreliance on China in the rare earths sector has encouraged these agencies, among others, to develop a more cohesive critical mineral strategy, their divergent permitting process remains a significant barrier. Additionally, inconsistencies between state and federal regulations often result in unnecessary bureaucratic delays which impacts the rate at which otherwise compliant mines can become operational. Reducing environmental regulations is not a necessary condition to facilitate the development of the USA's rare earths sector. Insead, streamlining the permitting process to more efficiently demonstrate compliance to these regulations will help to limit the local community and environmental impacts while enabling the USA to effectively pursue its critical mineral strategy in the rare earths sector.

Chile's Mining Industry: An Overview

The mining sector has been a critical source of sustained economic growth for Chile, benefiting the country in terms of external commerce and domestic industrial development. When well-managed, natural mineral resources have the potential to offer countries the chance to achieve sustainable economic growth and reduce poverty[175]. However, it is crucial that companies are held accountable by governments for mitigating potentially harmful effects of the industry, such as environmental degradation and harmful runoff as discussed above. Because Chile's REE industry is still in its beginning stages, we use the copper and lithium industries as proxies to discuss areas of strength and areas of improvement for the Chilean mining sector. Although extraction and processing methods of each mineral are certainly distinct, the economic, social, and political implications of these industries are more similar to those of rare earths than precious metals like gold or silver. Using the country's copper and lithium industries as a point of reference, the following analysis surrounding the regulations, legislation, and stakeholder interests serves as the basis for our ultimate policy recommendations for Chile's incipient rare earths sector.

[175]The World Bank. 2010. "Improving Mining Benefits for Communities." Text/HTML. World Bank. 2010. https://doi.org/10/06/15/improving-mining-benefits-for-communities.

Based on our analyses, Chile's mining sector is particularly strong in the following areas:

1. Quality/quantity of mining resources and reserves
2. Existing infrastructure and technical capacity
3. Legal framework

However, there is room for improvement in several key areas to prepare for potential REE mining expansion. Based on our analysis of the industry trends in the global rare earths sector and the specific nature of Chile's copper and lithium, this section identifies the following points as potential areas of improvement:

1. Public participation and Indigenous rights
2. Energy, water, and environmental concerns
3. REE background and technology

Quality and Quantity of Mining Resources and Reserves

In conjunction with lithium and copper, Chile holds significant rare earths reserves. The quantities of large mineral deposits in economically viable concentrations make Chile's mining sector as profitable as it is critical to the country's position within global supply chains. As a result, the mining sector is the largest proportional contributor to Chile's total exports by a wide margin. As of 2021, Chile's top exports are copper ore ($29.7B), refined copper ($20.8B), fish filets ($3.13B), raw copper ($2.55B), and iron ore ($2.54B)[176]. Chile's top trading partners are China, the United States, Japan, and South Korea, with exports to these countries totals $36.6 B, $15.1 B, $7.25 B, and $4.8 B respectively[177]. Given the preeminence of copper and lithium in Chile's mining sector, and economy overall, the vast majority of these minerals exported to its top trade partners are used as raw materials for their respective technology manufacturing sectors. Furthermore, as of April 2023, Chile has imported mostly goods from from United States ($1.99B), Switzerland ($582M), China ($325M), Brazil ($218M)[178]. Given the scale and

[176] OEC. 2022. "Chile (CHL) Exports, Imports, and Trade Partners | OEC." OEC - The Observatory of Economic Complexity. Accessed April 20, 2023. https://oec.world/en/profile/country/chl.
[177] Ibid. EOC.
[178] Ibid. EOC.

importance of international trade to the country's economy, Chile was the first South American country to join the Organization for Economic Co-operation and Development. Similarly, Chile is also a observing member of the Mercosur and active in the Asia-Pacific Economic Cooperation Forum, one of the largest trade blocs in Latin America[179]. Chile's network of free trade agreements and membership in various economic communities has enabled the nation to strategically leverage its coveted mineral resources to center itself within global supply chains.

As such, the country's mining industry represents some $317 billion or 15 percent of Chile's GDP; in 2021 and mining exports were over 62 percent of the country's total exports as of 2022[180]. Chile's economy is one of strongest in the Western Hemisphere, ranked by the World Economic Forum as the most competitive in Latin America[181], valued at $317.06 billion USD as of 2021[182]. Having significantly invested in the infrastructure and technological expertise to exploit its natural resource wealth, the mining sector is responsible for more than half of Chile's total exports and eleven percent of its GDP[183]. As a result, Chile controls 28 percent of global copper production and 22 percent of global lithium production. Furthermore, Chile's pre-existing copper and lithium industries bode well for diversifying into the REE sector; rare earths are almost always found paired with more common minerals — such as copper— for which Chile ranks number one worldwide. Copper is often found alongside the REE yttrium (Cu-Y), for example. As such, mining for REEs such as yttrium could potentially be extracted alongside copper in existent mines — with the proper technology. Although many nations hold rare earths deposits, they often lack the conditions necessary to harness the economic potential of these mineral resources. Because of Chile's pre-existing mining infrastructure, technical expertise, and advantageous global trade relationships, leveraging the country's rare earths resources would not require developing an entirely new and uncharted industry; rather, doing so would be a lateral expansion further diversifying Chile's already robust mining sector.

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[179]Op. Cit. Bertrand-Gallino.

[180]Proelss, Juliane, Denis Schweizer, and Volker Seiler. 2020. "The Economic Importance of Rare Earth Elements Volatility Forecasts." *International Review of Financial Analysis* 71 (October): 101316. https://doi.org/10.1016/j.irfa.2019.01.010.

[181]World Economic Forum. 2014. "Top 10 Most Competitive Economies in Latin America and the Caribbean." World Economic Forum. September 3, 2014. https://www.weforum.org/agenda/2014/09/top-10-competitive-economies-latin-america-caribbean/.

[182]The World Bank. n.d. "World Bank Open Data." World Bank Open Data. Accessed April 20, 2023. https://data.worldbank.org.

[183]International Trade Administration. 2022. "Chile - Mining." September 30, 2022. https://www.trade.gov/country-commercial-guides/chile-mining.

Existing Infrastructure

The capital invested to develop Chile's mining industry to its current scale has contributed significantly to the country's overall economic development economy. Specifically, factors including Chile's innovative technology, qualified labor force, and robust regulatory environment, along with its "advanced energy infrastructure, transportation network and strong legal framework, together with the quality of the mining resources and reserves"[184] have converged in such a way that has made the country's mining sector one of the most lucrative and competitive in the world. Recognizing these advantageous conditions since returning to democracy, over the past thirty years the Chilean government has taken an active role in promoting the mining sector as its primary means to achieve its national development goals. For example, as of 2016, the economic implications of this booming sector has enabled Chile to achieve achieve near universal access to clean drinking water, electricity from the national grid, and sewerage system connectivity[185]. The economic benefits resulting from Chile's growing mining sector has created a positive feedback loop where as Chile becomes more developed, so too does its mining sector and vice-versa.

Chile not only holds large raw mineral deposits, but also has developed the complex and technologically sophisticated infrastructure necessary to transport and process the minerals once they have been extracted. Additionally, Chile has a free trade agreement with the USA; this makes sourcing minerals from Chile an attractive investment destination for electric vehicles producers seeking IRA subsidies[186]. The high transportation capacity would facilitate trade and movement of goods. Chile's transportation systems are also particularly strong, with a developed highway network and port system, which more than doubled maritime transportation capacity between 2004 and 2014 and is among the highest in Latin America[187]. Chile, furthermore, leads the region in urban development infrastructure projects such as the Santiago metro and wastewater treatment system. Many of these projects succeeded through mobilizing private finance by adopting and refining the concessions model of 1992 for delivering infrastructure. Through this program, Chile has completed more than 82 projects worth around $19 billion

[184]Op. Cit. The Law Reviews.
[185]OECD Public Governance Directorate. 2017. "Gaps and Governance Standards of Public Infrastructure in Chile Summary."
[186]Rachman, Joseph. 2023. "Chinese Firms Dominate Indonesia's Nickel Market." 2023. https://foreignpolicy.com/2023/04/17/china-indonesia-nickel-metals-inflation-reduction-act/?utm_source=PostUp&utm_medium=email&utm_campaign=News%20Alerts&utm_term=83938&tpcc=News%20Alerts.
[187]Ibid. OECD.

USD[188]. The government has furthermore prioritized growth in education and health sectors, and targets improvement opportunities in these sectors. These infrastructures are reinforced by strong institutions and government capacity. Although Chile's government framework has been criticized for lack of medium- to long-term infrastructure planning, the strong existing institutions would allow Chile to smoothly transition into the REE sector.

Legal Framework

Although Chile lacks laws which specifically mention REEs, their strong legal system and existing policy ecosystem offer a strong regulatory framework for increasingly environmentally friendly legislation. The main mining authorities in Chile are the Ministry of Mining and the National Geology and Mining Service. The government also has the Chilean Copper Commission, which "advises the government concerning policies, strategies and actions that contribute to the development of the industry and oversees the interests of the state in its mining companies"[189]. Chile's mining legislation is divided into a number of laws, most notably the Constitutional Organic Law Concerning Mining Concessions, and the Mining Code. The Chilean constitution outlines that the Chilean state has absolute, exclusive, inalienable and imprescriptible ownership of all mines, regardless of the property rights over the superficial lands wherein those mines are located[190]. Chile's mining code continued in the enactment of the Constitutional Organic Law Concerning Mining Concessions (*Ley Orgánica Constitucional Sobre Concesions Mineras,* or LEY 18097) of 1982. This asserted property rights to mining concessions and provided guidelines for mining rights with Article 1 stating that "las concesiones mineras pueden ser de exploración o de explotación" (mining concessions can be used for exploration or exploitation[191]). This Mining Code regulates mining practices and designates access to water to the owner of the mining concession to the extent that the water is necessary for the exploration, exploitation or processing of the site[192].

The following institutions are particularly relevant in the legal frameworks of Chile: SERNAGEOMIN, the national geology and minerals service which performs services such as mine safety inspections and review of mine closure plans; and CONAMA, which has been the

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188Ibid. OECD.
189Op. Cit. The Law Reviews.
190Chile Constitution.
191Author's translation.
192Op. Cit. The Law Reviews.

national environmental agency, which completes basis environmental requirements, reviews and approves environmental impact evaluations, etc[193]. The Chilean system works unitarily, meaning that the regional administration is appointed by and works with the central government. Compared with other countries in the region, the Chilean system also maintains fairly transparent processes for allocating mineral revenues[194].

Chile's current president, Gabriel Boric, represents the leftist Convergencia Social (Social Convergence) political party. Through his time in office, Boric has headed a number of initiatives intended to offer more environmental protections and more rights to marginalized groups, including Chile's Indigenous population. In September 2022, President Boric oversaw a constitutional referendum intending to vote on a new constitution to replace the country's existing constitution that was first promulgated by the Agosto Pinochet regime in 1980. Although the new constitution failed to pass, it included articles which would have impacted the mining industry, including "new environmental requirements, the constitutionalisation of the rights of Indigenous communities, the modification of the status of waters"[195]. However, the constitutional convention ended with a vote to keep the pre-existing constitution and reject Boric's proposal. In July 2022, the Chilean government released a tax reform bill that includes new mining royalties[196], which would create a fixed sales royalty of 1% for large mining companies. While this would increase revenues for the government, companies complained that the tax burden was too high, and the bill was voted down on March 8, 2023.

Recently, however, in April 2023, the Chilean government announced the country would begin the process of nationalizing its lithium industry[197]. Although attempts to fully nationalize portions of the mining sector have been made in the past, such as the unsuccessful effort to nationalize Chile's copper industry under the Allende administration in the 1970s, the Boric administration's effort to nationalize Chile's lithium industry greatly differs, because unlike copper, lithium is nearly universally recognized as a critical mineral. Furthermore, Chile is the largest exporter of lithium, and like the rare earths sector, the nature of the global lithium trade is

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[193]SDSG (Sustainable Development Strategies Group). 2008. "Report: Current Issues in the Chilean Mining Sector." https://static1.squarespace.com/static/5bb24d3c9b8fe8421e87bbb6/t/5c3bcf8b2b6a28e8ada4e4ce/1547423629752/10-10-08-CHILE-REPORT.pdf.
[194]Ibid. SDSG Report.
[195]Op. Cit. The Law Reviews.
[196]Aclara Resources Inc. 2023. "Aclara Resources." 2023. https://www.aclara-re.com/operation/operations.
[197]https://www.reuters.com/markets/commodities/chiles-boric-announces-plan-nationalize-lithium-industry-2023-04-21/

concentrated to a select few nations, meaning that nationalizing this industry would corollarily center the Chilean government within geopolitically strategic supply chains. It is important to note, however, that this would not be a full nationalization; rather, it would be done in such a way to further encourage cooperation with domestic and foreign private sector actors under a policy framework with increased state oversight. Although it is too soon to tell what the long-term implications of Chile's recent effort to nationalize lithium will be, it is clear that the country has recognized the strategic value of its own mineral deposits in relation to global technology supply chains. As a result, this could be a signal that if Chile becomes a major player in the rare earths trade, then the county might take similar measures to guarantee state control over this strategic resource.

Public Participation and Indigenous Rights

While the legal framework of Chile's mining industry is relatively strong, local communities remain disillusioned with their ability to participate and be heard in mining legislation and disputes—especially marginalized Indigenous communities. While the country has undertaken recent efforts to include more public participation and guarantee rights for Indigenous peoples, the Boric administration has struggled to make these goals a reality. The lack of public participation can have devastating consequences for communities. As discussed, the complex processes involved in the extraction and processing of REEs can have particularly harmful environmental effects which have the potential to wreak havoc on local communities.

In 1989, the Chilean government enacted the Indigenous and Tribal Peoples Convention, 1989 (No. 169), which established amongst other goals that "Indigenous and tribal peoples shall enjoy the full measure of human rights and fundamental freedoms without hindrance or discrimination"[198]. This bill's most recent version was ratified in 2008, with stipulations that "Indigenous and tribal peoples are consulted and fully participate at all levels of decision making processes that concern their rights"[199] particularly regarding their lands, amongst other resources. The rejected 2022 constitution also planned to enumerate rights for Indigenous groups, including Article 66 which states that "Indigenous peoples and countries

[198]International Labor Organization. 1989. "Convention C169 - Indigenous and Tribal Peoples Convention, 1989 (No. 169)." 1989. https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C169.
[199]Op. Cit. SDSG Report.

have the right to be consulted prior to the adoption of administrative and legislative measures affecting them. The state guarantees the means for the effective participation of these, through its representative institutions, in a prior and free manner, through appropriate, informed procedures. and in good faith"[200]. However, the rejection of the constitution leaves many Indigenous rights in limbo, and Indigenous peoples continue to disproportionately deal with the burdens associated with the negative externalities of the country's mining sector.

According to Pietrobelli et al, 31% of recent mining projects in Chile were postponed due to conflicts with local communities and environmental problems[201]. Chile's environmental impact review system (SEIA, or Sistema de Evaluación de Impactos Ambiental) was created in 1994 and considered a "complicated and often confusing process"[202]. The SEIA requires a Declaration of Environmental Impacts (DIA) for smaller projects, or a Study of Environmental Impacts (EIA) for larger projects. If a project affects more than one region of Chile, the Federal Government under the National Environmental Commission (CONAMA) completes the review process. If the project impacts only one region, the Regional Environmental Commission (COREMA) reviews the case. This differentiation can cause a lack of cohesion between the state and federal agencies. All EIAs are available to the public online, and during the 60-day review period, the public including affected citizens, communities, NGOs, professional groups can submit comments to the appropriate government agency. However, there is no government system which requires companies to address these comments. If the environmental authority fails to meet environmental standards on their first submission, they may submit a second review phase—which does not allow public participation[203].

Energy, Water, and Environmental Concerns

The lack of opportunities for community members to participate directly in dialogue with mining companies often translates to unresolved environmental and safety concerns for local populations. The energy, water, and environmental concerns of the mining industry in Chile complement the concerns found in the lack of public participation and Indigenous rights. The

[200]Chile's Draft Constitution of 2022. "Chile 2022 Constitution - Constitute." Accessed April 20, 2023. https://www.constituteproject.org/constitution/Chile_2022D?lang=en.
[201]Op. Cit. Pietrobelli.
[202]Op. Cit. SDSG Report.
[203]Ibid. SDSG Report.

energy and water issues in Chile complement one another because much of Chile's power comes from hydroelectric dams—tying the energy sector to the water sector.

Concerns about electricity use are particularly relevant to the REE industry given the vast amount of energy needed to extract and refine the minerals to a grade suitable for export. Large industrial customers, mainly mining companies, are responsible for some 90 percent of electricity consumption in northern Chile, an area with only 6 percent of the population[204]. Part of the issue of Chile's energy shortages are the lack of domestic fossil fuels, which causes the country to import more than three-fourths of their energy needs. The importation of energy can lead to instability and stress on the system, as in 2008 when the government began to enforce energy-saving measures such as: "a 10% reduction of voltage supplied to domestic users, implying that supply will be dropped from the normal 220v to 198v; an extension of daylight-saving time to the last week in March; an enforced 5% cut in power consumption in government offices; distribution of energy-efficient lighting; and pledges from industry to save electricity by turning off non-essential machinery"[205]. The mining sector remains responsible for massive amounts of energy usage, and possible solutions — including increasing hydropower through dams — could cause environmental damage to fragile ecosystems. However, the mining of REEs, with increasing green technology implications, could mean that Chile's energy may be increasingly produced through cleaner and less contentious technologies using domestically sourced rare earths. However, the Chilean Consejo Minero reportedly estimated that 63 percent of the country's energy sources would be clean energy.

There are also major concerns involving the water usage involved in the mining industry. Mining costs increased 111 percent between 2005 and 2014, in large part due to the extremely high costs of transporting water from the sea to mines in high-altitude or desert-bound mining sites like those found in the Atacama region[206]. Although the 2022 constitutional proposition enumerated that access to water is a human right and "non-appropriable public good," the failure of this constitution means that the current system continues to allow for private ownership of water rights. Recent attempts to foster coordination between water-related policies struggled to create tangible impact for Chileans. The current National Water Code (1981) allowed for the development of a water market intended to increase "higher economic efficiency and

[204]Ibid. SGSD Report.
[205]Ibid. SDSG Report.
[206]Op. Cit. Pietrobelli.

conservation of water"[207]. This system allows the national government to allocate water resources to private companies for indefinite periods of time, and suffers from inconsistencies across different industries, including agriculture, land use, energy and mining. This lack of institutionalized central water policy creates tensions between industries and communities, and suffers from lack of communication between regions and municipalities.

The energy, water, and mining sectors intersect with concerns on environmental degradation. The Chilean mining sector's major environmental concerns include conflict over water use/scarcity; conflicts over energy allocation; controversy over damming free flowing rivers to develop the electrical grid; impact of smelter emissions on air quality.

Lack of REE Background and Technology

The Chilean state has historically been deeply intertwined with the mining industry. In fact, the country's legislation proved remarkably pro-mining through the twenty first century. Unlike Brazil and the United States, the REE industry in Chile has only just begun to be developed. In fact, very few companies have even begun exploring REE capacity in Chile. The Federal Government supports the mining industry in several ways. The government uses favorable royalty collection schemes and other pro-mining initiatives such as low tax rates on corporations as ways to attract foreign investors. The low tax rates create favorable conditions for investment by keeping taxes extremely competitive. Chile ranked among the top forty business-friendly tax rates in the world under the International Tax Competitiveness Index 2022[208]. However, despite their mining-favorable economic policies, there is a need for the Chilean government to provide more state support for REE development.

The current REE sector is dominated by Hochschild Mining (under its subsidiary Aclara Resources Inc.), who acquired a rare earths mining plot in Chile for total $60 million in 2019 from BioLantanidos Ionic Clay Rare Earth. The mines had a special concentration of high demand rare earths: notably, terbium, dysprosium, praseodymium, and neodymium. Hochschild reported that the extractions would not require the use of explosives, and that an "environmentally friendly" process would be used to extract rare earths without tailings dam[209].

[207]OECD Public Governance Directorate. 2017. "Gaps and Governance Standards of Public Infrastructure in Chile Summary."
[208]Tax Foundation. 2022. "2022 International Tax Competitiveness Index." *Tax Foundation* (blog). October 17, 2022. https://taxfoundation.org/2022-international-tax-competitiveness-index/.
[209]2020 Hochschild Investor Presentation (11/11/20).

Aclara owns concessions in the Maule, Ñuble, Biobío, and Araucanía regions of Chile, totaling to more than 451,985 hectares of land (1.1 million acres)[210]. Aclara is currently completing baseline studies to address issues raised by the Environmental Assessment Authority (SEA) during the original EIA process. Aclara Resources Inc. provides the public with an updated account of their press releases, annual filings, annual information forms, and updates on the pending status of the Preliminary Economic Assessment for their new facility, the Penco Module. In the exploration process, they drilled over 175 new holes through 2021 and 2022. The Penco Module includes a new resource area called Alexandra Poniente. However, the director of the Biobío Environmental Assessment Service (SEA), Silvana Suanes, expressed concern for the growth of the Aclara project. During the Penco citizen consultation—part of the environmental assessment process, as discussed—some 99.1 percent of the 7,500 participants voted against the continuation of the project, causing the company's permits to stall[211].

Chile's mining industry is dominated by private companies, but state-owned enterprises such as CODELCO still hold substantial quantities of mining properties. Chile incentivizes foreign investment in the mining industry through a business-friendly policy framework. However, despite the private company growth in Chile's REE industry, there is very little to no government involvement up to this point. The Boric administration has not officially commented on the potential growth of the industry, but the environmentally-centered articles of the proposed constitution could bode well for addressing the potential harmful effects of REEs.

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[210]Op. Cit. Aclara Resources Inc.

[211]Concepción, TVU | Televisión Universidad de. n.d. "Autoridades aseguran que el gobierno de Gabriel Boric decidirá el futuro del proyecto minero de tierras raras de Penco." TVU | Televisión Universidad de Concepción. Accessed April 20, 2023. https://www.tvu.cl/prensa/tvu-noticias/2022/03/01/gobierno-de-gabriel-boric-decidira-el-futuro-del-proyecto-minero-de-tierras-raras-de-penco.html.

Part V: Analysis and Recommendations

As the case studies demonstrated in Part IV, countries in the Western Hemisphere engaging the global rare earths trade must balance a myriad of social, political, and economic factors to maximize the viability of this sector. Because these factors are interconnected, failing to do so in one area places significant negative pressure on the others. Creating a policy ecosystem where otherwise antagonistic actors develop a mutually-vested interest in the success of a new REE operation, therefore, is critical. Because national governments have centered themselves as the ultimate power broker between domestic and international actors in the rare earths industry, given the global implications of the industry, for Chile's own rare earths sector to develop, our case studies have demonstrated the importance of negotiating local and multinational interests as well. In this way, Part V provides a final analysis and set of recommendations for Chile to maximize the potential of its incipient REE industry while simultaneously managing likely negative externalities. Based on both its pre-existing mining industry and evidence from our case studies, Chile would benefit from the following recommendations related to these three themes:

1. Private and public sector interaction
2. Regulation and impact
3. Technology and funding

Private and Public Sector Interaction — Political License to Operate

Throughout our analysis, we identified the relationship between the public and private sector to be the most salient factor determining the viability of a country's domestic rare earths industry. The public sector must take an active role in facilitating the development of a country's burgeoning rare earths sector and regularly implement adaptive policy solutions to maintain it; however, governments must be cautious as to not let this support devolve into a culture of state-sanctioned favoritism where lax regulatory accountability enables firms in the rare earths sector to prioritize profits at the expense of the wellbeing of the local environment and community. Because of this, the state serves as the "power broker" responsible for setting the terms of engagement between social, political, and economic actors so their interest converges under a framework conducive to developing a vested interest in mutually contributing the success of a country's rare earths sector.

For a country's REE sector to be sufficiently insulated from geopolitical vulnerabilities, the whole supply chain process must be diversified, not just the mining process. However, the profit margins generated by mining rare earths are proportionally larger than operations refining these minerals, meaning that investors interested in financing the extractive portion of the rare earths sector are often less willing to venture into the less profitable but strategically important refining industry. As such, doing so requires public sector support to compensate for lack of private sector interest. For example, while Brazil's niobium sector exemplifies how a government can create a policy environment favorable to both exploiting new rare earths reserves and supporting the operations of existing firms like CBMM, these minerals produced in Brazil are still largely exported to China for refinement. Conversely, the United States has passed legislative initiatives and provided financial incentives in the form of tax-breaks and subsidies to encourage the development of its own domestic REE mining and refining sector. However, although the United States is still largely dependent on China, because of this investment in expanding both the country's domestic mining and refining sector, the United States is better positioned to incrementally reduce its exposure to global supply chain vulnerabilities as these industries convergently mature compared to Brazil which is also increase the scale of its rare earths production without without correspondingly investing in home-soil refining solutions. Although the nature of Brazil's trade relationship with China is different from that of the USA because of the geopolitical leverage the country holds with its niobium export monopoly, this leverage is only guaranteed insofar as other countries do not develop their own competing niobium sector undermining Brazil's strategic market position. Because of this, emulating the United State's two-pronged approach of providing legislative and financial incentives to spur the development of both its rare earths mining and refining sector will be critical for Chile to fully reap the economic benefits of the industry without compromising national security.

Developing domestic rare earth mining and refining initiatives in tandem would allow Chile to better dictate the terms of its own international trade relationships. Because of the multitude of countries producing similar raw materials, commodity exporters at the base of the value chain often compete with one another to provide the base materials used by a comparatively more limited number of countries higher in the value chain. Within this context, the disconnect between a vast supply of similar goods with a more limited demand often puts downward pressure on the price of commodities overall. This is particularly evident in the mining sector where copper prices are often indicative of the health of the global economy because the value of raw copper is ultimately determined by the world's overall consumption of end-products using this mineral. However, given the unique nature of the industry, rare earths serve as an exception to this trend in the commodity export sector. Because mining operations are dispersed amongst a comparatively small number of nations, and refining amongst even fewer, countries both producing and refining rare earths have a proportionally greater degree of control over the global trade than in other mineral export sectors with more competing actors.

China's dominance in the rare earths sector exemplifies this; although countries around the world are interested in finding alternative sourcing patterns to limit their the risks associated with their overexposure to China in this sector, the lack of new market actors has enabled China to continue to use its domestic rare earths sector as a political tool to shape the behavior of countries higher up the value chain. Similarly, Brazil has been able to somewhat do this with its own niobium monopoly; however, because this raw niobium is almost exclusively exported to China for refinement, Brazil's capacity to leverage this monopoly is largely limited to one nation. By developing both mining and refining operations, Chile will be able to center itself as a trade partner between otherwise adversarial factions, elevating its global standing by forcing them to compete for Chile's coveted rare earths exports. In this way, a comparatively small public sector investment in spurring the development of Chile's domestic private-sector led rare earths mining and refining industry will have a proportionally larger impact on the country's international power projection ability. Countries are willing to pay a premium to secure supply chains of rare earths sourced outside of China; for example, South Korea and Japan both bought 15% stakes in Brazil's CBMM, valued at nearly $2 billion respectively, in the wake of the 2010 rare earths price spike. While Brazil is the only country in the Americas which has been able to successfully leverage its own domestic rare earths sector as a foreign policy tool, this success is limited given its own dependence on China. Because of the global interest in sourcing these minerals outside of China, but limited potential new market actors, with public sector support, Chile can maximize the utility of its incipient rare earths sector as a foreign policy tool by investing in both mining and refining operations to uniquely allow Chile as a commodity exporter to dictate the terms of trade. In this way, the "political license to operate" is essential for Chile's rare earths sector to develop the "economic license to operate" and vice-versa.

Despite the apparent geopolitical benefits, a rare earths industry in any given country will not emerge on its own. Through our case studies, we found that state support works well when policies offer tangible benefits to companies to foster innovation. In the United States, the Biden administration's initiatives such as the CHIPS and Science Act of 2022, the Bipartisan Infrastructure Law, and the Inflation Reduction Act all promote interactions between the private and public sectors by offering tax incentives, loans, and grants to develop the country's domestic REE industry. Companies can use these benefits to kick-start their operations, and the US government's emphasis on stockpiling REEs virtually guarantees a domestic market for actors willing to pay a premium for rare earths mined outside of China. Because of its already robust network of international free trade agreements and strong mining sector, Chile is better positioned to leverage its rare earths resources than anywhere else in Latin America. The United State's IRA initiative under the Biden administration, for example, will provide subsidies and tax breaks for companies sourcing rare earths domestically or from friendly countries with free trade agreements with the USA such as Chile. In this way, the United States has created a policy ecosystem establishing a market for Chilean-sourced rare earths. Because Chile already engages with the USA under a free trade agreement, expanding into the rare earths sector would not be an entirely new and uncharted economic endeavor for Chile; rather, its preexisting trade relationships and reputation as a business friendly market have laid the groundwork for facilitating rare earths exports to the USA. Because of this, public sector initiatives encouraging the development of Chile's rare earths sector would come as a lateral expansion further diversifying the country's already robust mining export sector.

By analyzing the divergent policy ecosystems between the United States and Brazil, the relationship between the state and the mining sector has proven to be of central importance to the overall viability of a country's REE mining sector. In both countries, the influence of the state has become the primary mechanism facilitating the development and expansion of the rare earths sector. In this way, the state has translated geopolitical concerns into domestic policy initiatives by providing legislative incentives for local firms to grow in their respective rare earths sector. Without this support domestically, for example, China was able to overtake the United State's position within the global rare earths trade in the 1980s. Conversely, Brazil was able to defend its niobium monopoly with state support for the country's niobium sector. When left up to market forces alone, a country is unlikely to develop a rare earths mining and refining industry in the short-term and also defend it in the long-term. Because of this, for a country to reap the unique and strategic geopolitical benefits as a rare earths exporter, the public sector must create a policy environment conducive to private sector investment.

Implementation of Regulations— Social License to Operate

While legislative initiatives are crucial for creating the necessary policy framework to develop a country's incipit rare earths sector, complementary regulations to manage the negative externalities associated with the industry are essential to generate public support and secure the social license to operate. By creating a policy and regulatory system where political, economic, and social actors develop a vested interest in the success of a country's rare earths sector, leveraging these resources is not framed in terms of whether or not it should occur, but by whom and on what terms. Although legislative initiatives can facilitate the profitability of an enterprise, robust regulatory accountability mechanisms ensure these operations do not come at the expense of the wellbeing of the local community or environment, undermining the viability of the entire operation.

Local and international factors have a dialectical relationship informing policy decisions and the regulatory framework surrounding the REE industry, with the state serving as a critical mediating influence determining the trajectory of the sector's development. Using Brazil and the United States as case studies, the two countries' divergent approaches to supporting and managing their respective firms operating in their respective REE sectors has proven to be a culmination of historical, ideological, and geopolitical influences informing national development. Brazil's statist developmental strategy has shielded their domestic REE sector from foreign competition while simultaneously establishing a regulatory framework conducive to soliciting international investment. As a result, certain firms have gained a "privileged" status within the country, determined by convergent public-private sector interests. This has occurred, however, largely without taking local or environmental actors into consideration because the growth of these "privileged" firms in the REE sector has become a policy instrument for Brazil's national development and international power-projection. While protectionist policies have encouraged the consolidation and growth of pre-existing firms, these same legislative initiatives and regulatory passivity have encouraged small-scale mining operations in opaque jurisdictions like the Amazon, a reputational risk potentially damaging Brazil's international competitiveness.

With Brazil at the center of global critical mineral policy initiatives given its market domination in the niobium trade, the nation has carved out a competitive niche within the rare earths trade otherwise monopolized by China. State support has been critical to not only establishing this niche, but also defending it against foreign competition through protectionist policies. This, however, has come at a cost. While individual firms like CBMM operate under a largely sustainable framework, recent efforts to further expand the industry into the Amazon have been operationalized in such a way that exacerbates social conflict and environmental degradation in ecologically sensitive regions. While state support has proven to be a critical factor defending Brazil's rare earths niche, the nature of the relationship between the public and private sector has evolved and expanded in scope throughout history in response to similarly evolving internal and geopolitical factors. As a result, large-scale mining interests and the government's efforts to pursue its development and national security goals have increasingly converged to service the rising demand for niobium in the global economy, albeit at the expense of Brazil's international reputation as a sustainable rare earths sourcing partner. Although Brazil is officially a non-aligned nation within the rising US-China tensions, the increasingly unsustainable nature of Brazil's domestic niobium industry has become a supply chain liability. Geopolitical factors have translated into an extractive environment which inflames acute social and environmental concerns within the nation, and as a result, Brazil's internal volatility in this sector is proving to be a source of volatility in global supply chains in itself.

Conversely, as of recently, the REE sector in the United States has comparable public sector support within a robust environmental regulatory framework, enabling easier market entry for new domestic firms while also placating local community concerns by providing avenues for legal recourse against mining operations for any given infraction. In this way, mining operations can be held accountable by both regulatory agencies and the local citizenry alike. Because of this, it is in the self interest of firms in the United States to not assume that the overall geopolitical and economic benefits of their operations do not jointly eclipse the interest of local and environmental actors. For example, to address safety concerns related to the sector, the United States passed a series of legislative initiatives and invested in clean-up operations related to the devastating 1979 Navajo Nation radioactive water spill. Although the local community and environment are still suffering from the impacts of the spill to this day, the regulatory loopholes responsible for the spill in the first place have since been closed, reducing the likelihood of another similar event in the future.

Regulatory agencies do not derive their legitimacy from their mere existence; rather, public confidence in mining operations and government enforcement mechanisms alike comes from an agency's capacity to consistently and transparently hold actors accountable. As a result, meaningful regulation should be prioritized; governmental funding and enforcement of regulations are crucial to creating meaningful impacts. This means that adequate funding allows agencies to have the financial means to regulate the mining sector effectively. Because of this, effective private sector due diligence operations and public-sector permitting mechanisms must work in tandem. However, as seen in our case studies, although both the United States and Brazil have rigorous permitting processes, the specific nature of these permitting processes informs how actors in each jurisdiction engage in their respective rare earths sector. For example, because the country has multiple levels of jurisdictional overlap, the permitting process in the United States is not vertically integrated; rather, local, state, and federal governments each have their own permitting systems. As a result, mining companies must navigate this complex bureaucracy and comply with the highest regulatory standard for any given requirement, even if two of the three jurisdictions have crafted their own respective regulations. New rare earths operations in the United States often do not cite having to develop environmentally and socially conscious production systems as a major barrier to entry; instead, demonstrating this compliance through an overly byzantine permitting process often causes significant and costly delays undermining the profitability and overall viability of a new operation.

Alternatively in Brazil, however, bureaucratic barriers did not evolve as a deficit in its process, but as an intentional "core competency" of the country's permitting system and developmental model. Because Brazil's statist economic model established a hierarchical system of public-sector favoritism for certain firms deemed critical to advancing the country's national interest, mining operations with this privileged access to the state have the capacity to advance through the country's otherwise byzantine permitting process with relative ease. In this way, the government has shielded these privileged large-scale firms from foreign and domestic competition alike through selectively enforced bureaucratic mechanisms. These large-scale firms pay rents to the government and help Brazil's international power projection via commodity exports which further encourages the state to develop a policy and regulatory system conducive to their profitability. For example, although Brazil's mining and critical mineral policies nominally extols the importance of social and environmental actors, when the country updated its mining code in 2012 to specifically include rare earths, this was done so to ultimately expand the economic potential sector rather than codify industry-specific accountability mechanisms. Furthermore, although environmental and social protective measures exist nominally, this regulatory system has implicitly encouraged actors to encroach on legally protected land with minimal accountability provided their operations serve the interest of the Brazilian state. Because of this, small-scale miners in opaque jurisdictions, like Indigenous peoples in the Amazon whose efforts for self-determination is perceived by some as a threat to the power of the Federal Government, are often hesitant to registering their rare earths findings on their territory with the state, fearing the Brazilian government will assert their rights of eminent domain to develop the resources themselves or contract with a “privileged” large-scale firm to do it on their behalf. In this way, Indigenous mining operations have become criminalized, leaving them with little legal recourse to assert their territorial rights. Furthermore, non-Indigenous *garimpeiros* (artisanal miners) operating in the Amazon have received tacit government approval in recent years to exploit rare earths reserves on nominally federally protected lands because their operations indirectly allow the state to undermine the sovereignty of Indigenous territory by proxy and further its national development goals.

Given the lucrative potential of rare earths, the human and environmental cost of mismanagement in this sector, as a result, is correspondingly high. Rare earths are typically located in remote and ecologically sensitive areas often on or near land belonging to vulnerable communities such like Indigenous peoples, as mentioned in Part III. As a result, the rising demand for rare earths must correspond with increasing regulatory supervision as well; using more environmentally friendly methods of mining and refining help to ensure the short-term economic gains in this sector do not undermine the long-term environmental and social interests of impacted communities. For example, Zhang (2022) suggests that departments of land and resources at all levels of government should rectify registration of polymetallic minerals, including demarcating rare earth mineral resources and re-examining the exploration licenses and mining licenses issued in these areas[212]. Economic gains and regulatory accountability, as a result, should not be conceptualized as diametrically opposed; rather, regulatory accountability, when accompanied with legislative initiatives like tax incentives or subsidies, can help facilitate the profitability of the rare earths sector without compromising local community and environmental concerns impacting a firm’s social license to operate.

These regulations cannot just exist on paper—they must also be enforceable. Brazil’s permitting and regulatory system serves the interest of the state and the “privileged” actors

[212]Op. Cit. Zhang, 8.

operating on its behalf. In contrast, the multitiered permitting system of the United States gives community and environmental actors a proportionally larger voice at the local, state, and federal level at the expense of efficiently developing new mining operations. In this way, what is considered a “flaw” in one system is a “function” of the other. While the United States took measures to update its regulatory code and hold actors accountable to prevent another disaster similar to the 1979 Navajo Nation radioactive spill, Brazil’s relatively unchanged system has meant that firms like CBMM have only recently begun settling lawsuits dating back to the early 1980, if they get heard at all. However, more stringent regulations without complementary initiatives to disincentive firms from sourcing rare earths from foreign jurisdictions with lower regulatory standards partially contributed to the United States eventually ceding its monopoly in the sector to China; at the same time, however, government favoritism and protectionist policies helped Brazil to defend its position in the global niobium trade. For Chile to maximize the potential of its incipient rare earths sector, it must draw upon the lessons from Brazil and the United States so that its permitting and regulatory system efficiently advances Chile’s national interest without disregarding local and environmental concerns.

As seen in Part IV, Chile’s current mining industry operates under a strong regulatory framework. However, the country lacks REE-specific regulations; under the Boric administration, in 2022 Chile attempted to pass a new constitution and tax reform bill which would have entailed greater protections for the environment and Indigenous local communities, as well as stricter tax laws for mining companies. Although these initiatives ultimately failed and remain controversial, the fact that efforts to include historically marginalized interest in legislation bodes well for Chile’s burgeoning rare earths industry. While Brazil’s 2012 mining code revision to include REE policy helped the country to solicit international investment without ceding the sovereignty of the country’s mineral resources to foreign firms, this initiative critically overlooked conceres from local and environmental actors. This established a dangerous precedent for the country to further revise the mining code in 2017 which made it easier to mine on Indigenous lands despite fervent community protest. For Chile to maximize the potential of its incipient rare earths industry, it must craft a policy environment through which socal, political, and economic interests are weighted equally.

Notably, although Chile’s existing infrastructures are strong, there is room for improvement. In particular, the lack of water rights creates tensions between the public and private sectors. The Chilean government would benefit from a federal-level water policy which encompasses all industries and strengthens the institutional framework for water management[213]. Because of this, efficient inter-governmental accountability is critical as well. To avoid a conflict of interest, the political branch responsible for legislative and fiscal initiates to spur the development of Chile's rare earths sector must be separate from the agency responsible for regulation of the sector. If development and regulation responsibilities are delegated to a single agency, then one core capacity is likely to take precedence over, undermining the legitimacy of any policy or regulatory initiative.

[213]Op. Cit. OECD.

Technology and Funding — Economic License to Operate

The future economic profitability of the REE industry relies on the development and expansion of new technologies which facilitate extraction and processing while mitigating negative environmental impacts. Public sector support to implement policy initiatives conducive to the profitability of the rare earths sector, with complimentary regulatory provisions to manage its negative externalities, will be critical to spurring the short-term development of the industry. However, for Chile to stay competitive in this sector once it matures, the public sector must take an active role in developing new and innovative technology and research initiatives to guarantee the long-term viability of its rare earths sector. Chile is not alone in terms of its rare earths potential globally, so other new market actors are likely to emerge in the future as well. Because of this, investing in not only the development and growth of Chile's rare earths, but also in technological research will help ensure the country remains competitive in the long-term.

New technologies are necessary to avoid the harmful methods of extraction and processing discussed in Part III. These harmful and environmentally degrading methods of extraction are far from the only existing methods of production. Various research institutions and private companies have began to develop more sustainable mining and refining practices which include a more efficient, clean, and environmentally friendly method of smelting and separation[214]. For example, in 2021, Dong et al. at Penn State and the Lawrence Livermore National Laboratory (LLNL) identified a new, more environmentally friendly method of extracting REEs. This method uses a protein called lanmodulin, isolated from bacteria, which can separate REEs from other metals. The authors noted that "current REE extraction and separation processes require high energy consumption and pose severe environmental burdens that impede the development of a diversified REE supply chain and undercut the environmental benefits of clean energy technologies"[215]. This development comes amongst a surge in research related to sustainable techniques, calling for an increase in experimentation and innovation in methods of processing and extracting REEs with the least environmental harm. However, although the real-world applications for these exciting developments have yet to materialize,

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[214]Op. Cit. Zhang, 5.
[215]Dong, Ziye, Joseph A. Mattocks, Gauthier J.-P. Deblonde, Dehong Hu, Yongqin Jiao, Joseph A. Jr. Cotruvo, and Dan M. Park. 2021. "Bridging Hydrometallurgy and Biochemistry: A Protein-Based Process for Recovery and Separation of Rare Earth Elements." *ACS Central Science* 7 (11): 1798–1808. https://doi.org/10.1021/acscentsci.1c00724.

state-supported research advances have the potential to ameliorate community and environmental concerns impacting a firm's ability to secure the social license to operate.

Initially in the 1940s, technological advances are what allowed the United States to develop its original monopoly within the global rare earths trade. Similarly, the Brazilian government took an active role in investing in niobium research to discover new applications for the mineral so its domestic firms like CBMM could increase global sales. In this way, national governments of the United States and Brazil influence global market trends to increase the attractiveness of their own rare earths sourced domestically. Furthermore, in conjunction with state-sponsored support, the current salience of REEs in geopolitics create a strong environment for research grants and tax incentives for sector expansion. While local community and environmental concerns surround any mining operation, domestic regulations ensuring the sustainable production of rare earths will be particularly critical to addressing global supply chain issues surrounding the lack of sustainably sourced raw materials for the green energy transition. If Chile is able to develop a policy and regulatory environment which facilitates the economic viability of the sector while managing its social and environmental negative externalities, then rare earths sourced from Chile could become uniquely competitive in relation to the global green energy transition. Although technology like solar panels, electric vehicle batteries, and wind turbines are critical for reducing our consumption of fossil fuels and mitigating the impacts of climate change, the rare earths used in these applications are often sourced through environmentally damaging extractive operations themselves. Providing funding for technical research and establishing a regulatory framework to make the extraction and refinement of rare earths as sustainable as possible would not only help to address local community and environmental concerns, but it would also uniquely position internationally Chile as an attractive sourcing destination for rare earths to make entire green technology supply chains truly green from top to bottom.

Additionally, the Chilean government could further reinforce favorable political and economic conditions to solicit foreign investment to help with technology transfer to start the new industry. Alternatively, the Chilean government could lease technologies from other countries, such as the United States, as they become available. For example, this could involve working with other countries and paying a licensing fee for the technology—therefore not removing a national resource and not losing the revenue. Through a grant system, the government could both fund internal research and also potentially buy or lease technology from other international firms.

As mineral recycling technology improves, less rare earths will need to be mined overall to satisfy global demand for these raw materials. Only a fraction of rare earths are currently recycled because these initiatives have not yet reached a critical mass or a level of technological sophistication to become widespread and sufficiently profitable. Given the global interest in rare earths recycling technology initiatives, however, further developing this technology could prove to be strategic to guaranteeing Chile's long-term influence over the global rare earths trade. Developing a domestic recycling industry to complement its production and refine sectors could strategically position Chile at both the beginning and end of a curricular economy. In this way, even rare earths produced outside of Chile would potentially have to pass through the country to be recycled and eventually reintegrated into global supply chains. Because of this, if the Chilean government invests in research to develop the world's first economically viable rare earth recycling technology systems, then the emergence of new rare earths exporters would not threaten Chile's overall position in the global trade. Although recycling is just one potential avenue of exploration, the precedent set by the United States and Brazil demonstrates how government funded research can create market opportunities for Chile to spur the demand of its own domestically produced rare earths, guaranteeing the long-term competitiveness of its position within the global trade.

Part VI: Conclusions

In 2023, China continues to dominate extraction and processing in the rare earth elements industry. The 2010 crisis caused by China leveraging rare earths for its own geopolitical gain had global ramifications, leading countries like the United States and Japan, as well as the European Union, to incorporate REEs among their 'critical minerals' list—meaning these minerals are geopolitically important, and securing their production from allied nations or domestic production is a priority. The REE industry became particularly contentious given its applications in the defense sector, such as military aircraft and military-grade weaponry, as well as its implications for the green energy transition and advanced technology development. While we begin to transition away from fossil fuels to green energy, the national security of countries around the world will increasingly rely on sustainably produced rare earths. As a result, questions surrounding energy security and economic development will become increasingly inseparable from the national security concerns associated with rare earths global supply chains.

As China decreases REE exports and importers prefer to diversify their markets, a niche for new market actors in the global rare earths trade is emerging. The REEs industry is lucrative, albeit small in scale, but the economic implications of developing this domestic sector has global geopolitical implications. Chile, although given the size of its territory contains comparatively fewer rare earths resources than the United States and Brazil, is strategically positioned in this industry because of the nation's already robust mining sector, political stability, strong network of international free-trade agreements, and overall high investor confidence. The processing capacities of REEs continue to expand, and Chile could strengthen its ties with trading partners through the export of these minerals. However, through this capstone, we identified particular gaps within Chile's mining sector as well. Using lessons from the United States and Brazil, we developed a policy roadmap to facilitate Chile's entrance into the REE market by analyzing the two most successful REE industries in the Americas.

While China continues to lack regulation and participate in environmentally degrading practices, environmentally friendly and socially conscious production and refining alternatives exist. There is a need for increased awareness of the rare earths sector, as well as government and private sector cooperation for the positive growth of these critical industries. While there are strong geopolitical and economic reasons to enter the REE market, we caution countries with both emerging and existent REE industries to value the green approach to industry at the top and bottom levels of the supply chain. By securing the political, economic, and social licenses to operate, companies, communities, and governments may improve the mining sector in Chile, in the United States and Brazil, and in the industry on the global scale.

Contributions

Our capstone contributes to the Center for Latin American Studies by offering a cross-regional, multi-disciplinary analysis which covers three distinct countries in the Americas. Although we explicitly focus our analyses on the mining industries within Brazil, the United States, and Chile, we also create an illustrative comparison between these three countries and the rest of the world. Within this research project, we demonstrated the regional and global importance of Latin America as it relates to geopolitics and economics, but with specific emphasis on the often-overlooked parts of the mining industry. Rather than privileging one example over the others, we find that our geopolitical and economic evaluations of the REE industry in combination with specific case studies prove valuable and complex analysis of the burgeoning REE sector, particularly as it relates to green technology and efforts to combat the effects of climate change.

Across our three case studies, our analyses connect our goal to offer recommendations to the Chilean government and mining companies, and connect the entire region through extensive investigation of the mining industries in our chosen countries. Connecting three distinct case studies across region and temporalities revealed the major themes of this project. Our work stresses the importance of the smaller geopolitical players. Rather than a bilateral study of the United States and China, or an analysis of why the United States believes that Chile and Brazil should mine more, our analysis focuses on the Chilean lens and offers concrete benefits and drawbacks for Chileans. Our project emphasizes the growing need to grapple with the realities of climate change and shifts to the power grid. We revisit the question which inspired this project — if REEs are being used for green technology at the end of the supply chain, how can we ensure that the process is also green at the bottom end of the supply chain?

Our capstone weaves together our collective understanding of both Political Economy and Culture and Power, as well as States and Societies. We also drew from our particular areas of interest, from mining to environmentalism to national security. As such, we chose to present this capstone with as little bias as possible. Rather than focusing on corporations and incentives, we also illustrate concerns related to the struggles of local communities, including Indigenous groups across the Americas, to offer a nuanced viewpoint of a polarizing industry. Our deliverable, an article presented to AthenaLab in both Spanish and English, will detail our analyses and recommendations with the goal of improving the mining sector not only for companies or the government, but also the people.

Reflections

Our project grapples with a number of themes relevant to CLAS. First, situating Latin America as crucial to the world, in terms of economic expansion. More often, Latin American countries are referenced for their lack of economic opportunities, high opportunity costs, corruption, lack of infrastructure, and high crime rates. Although these areas certainly do impact Latin Americans and the region as a whole, we chose to focus instead on the possibilities for growth. By exploring themes such as environmentalism, access to water, Indigenous rights, land rights, and relationships between communities, companies, and the government, our project contributes to a changing narrative about Latin America—a narrative that promotes sustainable growth, poverty reduction, and strong democratic structures with concrete analyses. As we reflect on this work, we take pride in what we have accomplished and the respect with which we maintained for each of our case studies. This capstone project represents a hope for growth, a hope for a better future, a hope for more rights for communities and Indigenous peoples and a better environmental impact of the mining industry, which has historically caused immeasurable damage. We believe that our analyses and recommendations are applicable to the entire region, and even the entire world. We hope they help make the world a better place.

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