



ENERGY REPORT

Rare Earth Elements and National Security

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October 2014

This report is made possible through the generous support of the Alfred P. Sloan Foundation.

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Introduction

Many Americans received their first introduction to rare earth elements (REEs) in 2010, when the previously obscure commodities became the subjects of front-page headlines. Amid news of an alleged Chinese embargo on REE exports and ensuing concerns over potential supply disruptions, the news-reading public suddenly realized that these raw materials underpin products they care about. Policymakers and industry executives voiced concern over the many high-tech products reliant on REEs—ranging from U.S. defense systems to green technologies such as wind turbines and electric cars. Meanwhile, average citizens not motivated by policy battles or supply-chain vulnerabilities wanted rare earth products to make their cell phones vibrate, their headphones sound perfect, and their gasoline a little cheaper. As the occasional story had noted for years, REEs are wonder materials.¹ The central problem brought into sharp relief in 2010 was that China had cornered the supply.²

If ever China were looking for natural resources that its political leaders could use to extract high profits and geopolitical leverage, rare earths appeared a near-perfect candidate.³ At the time of the alleged 2010 embargo, Chinese firms accounted for 97 percent of rare-earth oxide production and a large fraction of the processing business that turns these into rare earth metals, alloys, and products like magnets. This near-monopoly was in a market with surging demand and intense political resonance in consuming countries. And the most dependent countries—primarily Japan and the United States, but also several European states—happened to be those over which China most wanted influence. Panicked policymakers in the United States and elsewhere began to consider extraordinary measures to protect their countries from potential Chinese leverage.

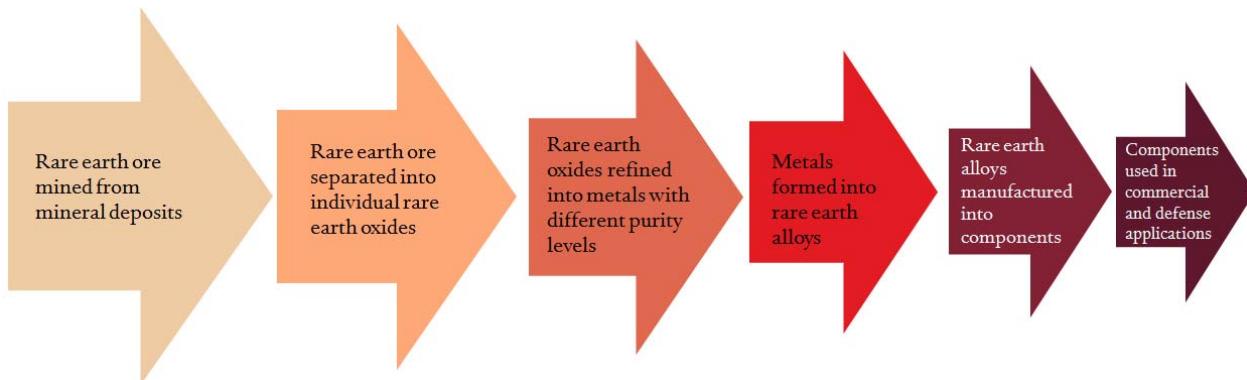
But even with such apparently favorable circumstances, market power and political leverage proved fleeting and difficult to exploit. China's advantages in the rare earths market were already slipping away as early as 2010 due to normal market behavior—particularly increases in non-Chinese production and processing capacity, as well as innovations that have helped to reduce demand for some of the most crucial REEs.⁴

Each crisis is different, but the largely successful market response in rare earths offers lessons for policymakers for the next crisis over raw materials imports. Future crises are unlikely to seem so perfectly orchestrated to make the United States and its allies vulnerable: the materials in question may be more prosaic or the country where supplies are concentrated may loom less ominously than China. But even in the apparently most-dangerous case of rare earth elements, the problem rapidly faded—and not primarily due to government action.

The Rare Earths Market

Though the rare earths market is often characterized as a single entity, this is misleading; there are seventeen different rare earth elements, each with distinct markets that have commercial uses. REEs can be divided roughly into two categories: light (lower atomic number) and heavy (higher atomic number). Additionally, global REE production generally involves two phases (shown in Figure 1)—mining and processing—with varying levels of processing required for different end uses.

Figure 1. Main Processing and Production Stages for REE Materials



Source: Government Accountability Office, *Rare Earth Materials in the Defense Supply Chain*, Briefing for Congressional Committees, GAO-10-617R, April 1, 2010, p. 11.

Until the 1990s, the United States was the dominant rare earths producer and China produced almost none. But Chinese companies enjoyed a combination of lower labor costs and relatively lax environmental regulations. Moreover, China's biggest rare earth mine also produces iron ore, providing another revenue stream to help cover the mine's fixed costs.⁵ By contrast, in 2002, the major U.S. mine shut down in the wake of complaints about environmental damage; the mine and associated processing plant needed capital investment and an arduous round of permit applications, and the owners (then Unocal) decided not to carry on.⁶ Meanwhile, Chinese production soared.

The Crisis... That Wasn't

After years of steadily gaining market share, by the early 2000s China produced 97 percent of the world's REEs. Because of REEs' extreme supplier concentration and the wide acceptance that these materials are vital inputs to military products, concerns over potential supply-chain vulnerabilities soon began to percolate around the developed world. In 2009, Australian government concerns led a state-owned Chinese company to scuttle its efforts to buy a majority stake in a new rare earth mine there.⁷ Around the same time, U.S. government agencies, led by the Department of Defense and the U.S. Geological Survey, quietly began to study the risks of dependency on China, and the U.S. Government Accountability Office (GAO) initiated a study in response to a congressional request.⁸

Within months of the publication of the GAO study, these concerns were seemingly realized. In early September 2010, in the midst of a maritime border dispute, Japan detained the captain of a Chinese fishing trawler. Afterward, China allegedly embargoed exports of rare earth oxides, salts, and metals to Japan. (Japanese companies insisted the embargo was real, even as the Chinese government officially denied it.) The choice of rare earths held particular stakes for Japan, the largest market for unprocessed or minimally processed rare earth materials. The imports feed Japan's high-tech industries that make important products like magnets, which Japan either exports to manufacturers or uses to make consumer products such as the Toyota Prius.⁹

Facing the supply disruption, Japan quickly released the fishing captain. The *New York Times* cited the high-profile event as a "humiliating retreat" for Tokyo.¹⁰ The incident seemed to indicate exactly how control over high-tech minerals mattered, and the fact that China was the source only made the situation worse. After Japan backed down, U.S. leaders wondered publicly how China had gained near-total control of such an important industry and called for policy responses to counteract China's market power.¹¹

Prices soared in the REE spot market in the wake of China's 2010 export cuts, especially as downstream users—companies that incorporate REEs into other products—filled inventories to protect themselves from future disruptions. Speculators also bought the stocks of many small mining companies that promised to develop new sources of rare earths around the world. But once buyers realized that actual supply to consumers around the globe was not that tight, prices plunged. Many of the new market entrants ran into financial trouble. Several brokers and downstream users had to write down the value of the inventories they had bought at the market peak. Furthermore, the postcrash low prices in 2012–2014 also hurt returns for some non-Chinese REE producers, delaying these producers' plans to ramp up to full use of their available capacity. The two-year post-embargo speculative bubble in rare earths had real economic costs.

Nevertheless, these costs hardly amount to a commercial or political victory for China. Four years on, non-Chinese REE investments are still making progress toward production.¹² REE supply continued throughout the 2010 episode, and the investments that came in the wake of the alleged export ban vindicated competitive behavior as a real constraint on Chinese suppliers' market power; increasing demand and market prices tend to spur entry of new supply-side players and projects, even when projects may take several years to reach fruition. The crisis also demonstrated that the demand-side constrains Chinese market power, as many rare earths users found ways to alter their

products to require less REEs. And politically, though China seemed to earn a victory in the 2010 confrontation with Japan, it actually achieved very little. The release of the fishing boat captain was a tactical victory, but did not yield any meaningful strategic change; Japan still administers the disputed islands and neither Japan nor any other country changed its legal views on the conflicting territorial claims. Ultimately, concentrated rare earths supply in China had limited economic and political effects.

Normally, a sanctioner expects sanctions to work by changing the target's economic cost-benefit calculation; demands that the target make significant concession need to be backed up by sanctions capable of registering palpable costs on a market of great importance (either economic or political) to the target country.¹³ Unfortunately for China, despite REEs' headline-grabbing role in so many high-tech industries, temporarily suspending exports cannot impose acute cost on even seemingly vulnerable targets like Japan. Why did the embargo not exact a greater cost on rare-earth dependent supply chains, either in Japan or in global markets? Why did it not manage to meaningfully deter Japan from asserting its territorial claims (beyond Tokyo's immediate, tactical decision to release the Chinese fishing boat captain)? The answer primarily traces back to three factors: increases in non-Chinese REE supplies that began well before the embargo, undermining China's supply-side leverage; administrative difficulties associated with enacting an embargo of this sort; and real-time adjustments in the market that circumvented the embargo.

SUPPLY GROWTH

Despite its relatively small size, the rare earths market managed to attract plenty of interest outside China prior to the 2010 supply scares. Motivated by expected increases in demand, investors in the United States, Japan, and Australia were already opening rare earth mines and building new processing capabilities by 2010, and other investors were moving ahead on mines around the world in places like Canada, South Africa, and Kazakhstan. The major investments made by Molycorp in the United States and Lynas in Australia and Malaysia started delivering non-Chinese rare earths to global markets by 2013.¹⁴

When rare earth prices surged in 2010, even more potential entrants swarmed. Hundreds of companies around the world started raising money for new mining projects. Rhodia, long established as a leading rare earths processor in Europe (physically in France though now owned by Belgian chemical company Solvay), ramped up its use of its existing plant capacity and accelerated plans to recycle rare earths, effectively creating a new source of supply to the global market. These new, non-Chinese sources hold the potential to profoundly change market dynamics. Although Chinese producers will still contribute a substantial majority of supply, competition from the rest of the world will moderate Chinese pricing power and feed high-priority end uses even in the event of a cutoff of all Chinese exports.

ADMINISTRATIVE DIFFICULTIES

One central lesson of the 2010 episode was directed more at Beijing than the rest of the world: the Chinese government discovered how difficult it is to control its domestic suppliers, who want to make profitable export sales even (or especially) in the face of policy decisions to restrict exports.¹⁵ Chinese quotas that restrict exports of rare earth oxides but allow unfettered exports of downstream

rare earth products might be intended to encourage additional value-added processing in Chinese plants, but they also encourage circumvention of the quotas. For example, in one such loophole, Chinese producers found that the quota did not apply to alloys that combined REEs with small amounts of other metals, so they exported minimally processed alloys to get shipments past Chinese customs inspectors.¹⁶

Smuggling also added to Beijing's enforcement difficulties. Many small-scale miners, especially those who exploit the southern Chinese ion-adsorption clay deposits (which are the main source of heavy REEs) often traffic their product across borders to Southeast Asian countries, sometimes by cooperating with organized crime networks.¹⁷ Comparing official Chinese export statistics to statistics on downstream rare-earth oxide consumption in countries like Japan reveals that probably as much as 20,000–30,000 tons of rare earth oxides were smuggled out of China each year in the late-2000s, roughly 15 to 30 percent of official production, depending on the year.¹⁸ The Chinese government announced plan after plan to control the smuggling and to force consolidation of small-scale miners into larger, easier-to-monitor companies, but they have thus far lacked the state capacity to make those plans stick.¹⁹ High levels of sustained government attention might eventually work, but the central government, beset with so many other economic and political challenges, has not yet managed to maintain enough focus on a relatively small industry.

REAL-TIME ADJUSTMENTS IN THE MARKET

During a crisis, trade patterns change to get products to their highest priority uses and many users find ways to reduce their actual use of the disrupted product. These adjustments can still be costly, but they decrease the overall cost of the disruption, and sometimes, the adaptation and innovation spurred by the crisis is actually nearly free or can even lower costs. An embargo or other supply disruption makes users think hard about an input that may have been relatively cheap before, meaning that the users had previously focused their attention on maximizing efficient use of other, more costly inputs. The new attention to the disrupted input can yield “low-hanging fruit” adjustments.

For example, at the time of China's 2010 export embargo to Japan, the largest-volume use of rare earths was in gasoline refining. But gasoline refining still works without rare earth catalysts, just slightly less efficiently; in fact, at the peak of the 2011 rare-earths price bubble (well after the embargo crisis), some refiners stopped using the rare earth catalysts to save input costs.²⁰ Even a major disruption of rare-earths catalyst inputs registered limited financial effects on the target.

That said, gasoline catalysts were not what most people were worried about during the China-Japan rare-earth embargo incident. Instead, most observers were focused on neodymium as an input to high-tech consumer products. Here again, however, even though the number of cell phones, hard disk drives, and even hybrid-electric vehicles is quite large, each one only requires a tiny amount of REEs in its components—for example, about a kilogram of neodymium for each Toyota Prius and a few grams in each cell phone.²¹ At that level of consumption, it does not take much circumvention, smuggling, resale of Chinese rare earths initially exported to other countries, or inventories held by downstream producers, to blunt or defer the impact of an embargo. The adjustment in international markets would surely have taken some time had the reported Chinese embargo lasted, and would have imposed some marginal cost of shifting trade routes, but an embargo would be unlikely to suddenly bring production of Priuses to a costly, screeching halt. Shuffling supplies might be

relatively difficult with products like rare earths, which lack a transparent international spot market, but commodity brokers' job is to find a way to match buyers and sellers, and some of them are good at it. The job of reshuffling will continue to grow easier as supplies from non-Chinese sources become more significant in global markets, too.

The magnet market also adapted through "demand destruction." Companies such as Hitachi Metals that make rare earth magnets (now including in North Carolina) found ways to make equivalent magnets using smaller amounts of rare earths in the alloys. Some users remembered that they did not need the high performance of specialized rare earth magnets; they were merely using them because, at least until the 2010 episode, they were relatively inexpensive and convenient. When the price rose following China's alleged embargo, users turned to simpler (and less material-intensive) rare earth magnets or even to magnets that included no rare earths at all. Such adjustments take a little time, thought, and design effort, but their availability means that supply interruptions often have a less dramatic effect than one might expect, based on precrisis demand.

If the likely costs of a continued embargo to the Japanese economy were manageable, why did Japan accept "humiliating defeat" in the fishing vessel crisis? Certainty about the real answer would require insider knowledge of secret Japanese government discussions during the crisis. One might guess that returning the fishing vessel captain to China, though imposing a short-term public relations cost, had little real effect on Japan's national interest. After all, Japan made no concession about its territorial claim to the disputed islands and it still controls the islands and patrols the surrounding water. Japan and China had an even more intense dispute over the same territories in 2012. China used what leverage it had with rare earths in a "use it or lose it" moment, as planned supply expansion outside of China was poised to still further reduce China's ability to manipulate the market for political gain.²²

Looking Ahead: Difficulties Exploiting Market Power in REEs Likely to Persist

Understanding the future trajectory of China's market power in rare earths requires a clear understanding of how rare earths are mined and commercialized. Rare earth mines take source material from the ground, use physical and chemical differences between the rare-earth containing minerals and other minerals to concentrate the product, and then use chemical processes to separate out the first material, known as rare earth oxides.²³ Those oxides are then converted into rare earth metals, combined with other metals into alloys, processed into components like magnets, and then assembled into goods such as generators, motors, and lasers used by ultimate consumers. Surveying trends in REE supply, demand, and processing, a combination of factors offer reason to expect that China's grip on the REE market will steadily diminish.

EXPANDING NON-CHINESE SUPPLIES

For rare earth oxides, total global production in 2012 was about 106,000 metric tons.²⁴ In 2013, Molycorp achieved full-rate production of what it calls Phase One of its Project Phoenix, yielding some 19,000 metric tons of rare earth oxides per year. (Molycorp has planned a Phase Two, which would double its production, but will not build the increased capacity until market conditions dictate.) Meanwhile, Lynas has been mining in Australia for more than two years, although it did not complete construction and permitting for its new processing plant in Malaysia until April 2013. Lynas now has the capacity to produce 11,000 metric tons of rare earth oxides annually and will soon complete construction to double that capacity, although it is methodically working out kinks in its process and waiting for higher market prices before actually expanding production of oxides to that level.²⁵

Though this expanded supply, led by Molycorp and Lynas, has helped alleviate overdependence on China, it may not have fully solved the problem for every rare earth material. For example, the main mineral deposits at Molycorp's Mountain Pass facility have low concentrations of heavy rare earths and of yttrium (which associates with the heavy rare earths in mineral deposits, even though it has a much lower atomic number).²⁶ Although Molycorp's innovative separation technology has the capability to produce all of the rare earth oxides, given current commercial conditions, Mountain Pass only makes a partially processed concentrate of heavy rare earths rather than fully separated heavy rare earth oxides.²⁷ The result is that according to a number of prominent forecasts, echoed in official U.S. government reports from the Departments of Defense and Energy, the world may experience a shortage of certain heavy rare earths in the near future.²⁸ But given the technology available and the production capacity already in place, non-Chinese suppliers like Molycorp could shift their output to include more heavy rare earths, if shortages were to emerge. Doing so would mitigate the shortage,

even though current non-Chinese production may not be enough to (by itself) eliminate dependence on China.

SHIFTING DEMAND

In the 2000s and especially at the height of the 2010 crisis, a spate of innovations seemed to dramatically increase demand for rare earth products, potentially increasing the value of any Chinese market power. These new products—many of them in the alternative energy sector—are real, and the markets may take off, further expanding demand for rare earths, if governments continue to subsidize deployment of alternative energy technologies.²⁹ Yet lingering concerns of overdependence on China may still be less serious than widely appreciated—in substantial part because not all demand trends are dangerous. Commercial demand for heavy rare earths is much lower than demand for light rare earths, and in many cases, new innovations are helping to further reduce this demand. This means that even relatively small non-Chinese rare earths deposits may still be able to meet market demand.³⁰

Take dysprosium as an additive to neodymium-iron-boron magnets. Only a small amount of dysprosium is needed. Though some uses that rely on substantial quantities of dysprosium (such as in the power train for electric-drive cars) have helped to stoke concern about materials shortages, innovations have reduced the amount of dysprosium needed for other uses below its already low tonnage. Both Hitachi (including its U.S. subsidiary) and a joint venture of Mitsubishi, Daido Steel, and Molycorp (in Japan) are building factories for new low-dysprosium magnets; Molycorp's Magnequench division also produces a dysprosium-free magnet that works at relatively high temperatures (although that production is currently located in China).³¹

Finally, manufacturers of products that use heavy REEs are carefully considering whether they can shift to another type of rare-earth permanent magnets, made from samarium mixed with cobalt, or can otherwise modify their designs to eliminate the need for dysprosium.³² The lesson here is that downstream markets are already adjusting to the changing supply picture through normal market mechanisms.³³

EXPANDING PROCESSING CAPACITY OUTSIDE OF CHINA

Beyond innovations helping to reduce overall demand, expanding processing capacity (including advances in recycling of REEs) is also reducing China's potential market power. Chinese market share of REE processing remains considerable and it is rising in some parts of the supply chain. For example, Chinese factories (including a number of foreign-owned ones) have recently increased their share of the market for neodymium magnets to as much as 80 percent.³⁴ But that market share is at current market conditions and China's ability to exploit its high market share is increasingly constrained by processing capabilities elsewhere in the world.

For some important rare earth products, no processing is needed; oxides are actually the end-use product. This is the case for high-volume uses such as lanthanum oxide, which helps to maximize gasoline yields in oil refineries, and for cerium oxide in automobile catalytic converters and in glass polishing.³⁵ For those products, the Molycorp operations in the United States and Lynas operations in Australia and Malaysia have broken the Chinese monopoly. In fact, because the mineral deposits produce fixed ratios of lanthanum and cerium oxides to neodymium oxide, and because neodymium

oxide is driving mining volumes, many forecasts predict a material surplus of cerium and lanthanum in the years to come, meaning low consumer prices.³⁶ The producers are actually looking for new markets for the “excess” cerium oxide and Molycorp has started to sell a new, proprietary, cerium-based water treatment product.³⁷

On the other hand, some uses of rare earths, like magnet and laser production, require additional processing steps beyond the separation stage—other phases of the supply chain over which Chinese suppliers could in principle gain a dominant position.³⁸ For those uses, Chinese companies operate factories at all stages of the rare-earth supply chain, but so do companies in Japan and Europe. The United States, too, has factories at all stages, including an Arizona plant that produces metals and alloys for magnet production, plants that produced samarium-cobalt magnets from Chinese-supplied rare earth alloys even in the years when China was most dominant in the raw material market, and now a plant that produces neodymium-iron-boron magnets.³⁹

The non-Chinese processing capacity has an especially important role with respect to the heavy REEs, where physical supply from non-Chinese mines has expanded the least. Deposits around the world that are especially rich in heavy rare earths still remain a long way from commercial sales—a mix of permitting issues, the need for substantial infrastructure around greenfield mines, and the need to develop new techniques to exploit geology that differs from the established rare earth mines.⁴⁰ But even though Molycorp and Lynas do not currently sell heavy rare earth oxides, their facilities still contribute to current heavy rare earth supplies, because Lynas and Molycorp both ship heavy rare earth concentrates that they dig out of their mines for processing elsewhere. In the past, some analysts feared that would mean processing in China, maintaining dependence on a single country’s policies for global access to important REEs. China still might well be a logical destination for Molycorp’s heavy rare earth concentrates—when Molycorp bought Neo Materials in 2012 to expand its technical capabilities in downstream processing, it acquired several plants in China.⁴¹ But it is no longer the only destination. Lynas, for example, has a long-term contract to supply concentrates, including heavy rare earth concentrates, to Rhodia’s separation plant in France.⁴² Rhodia can also buy Molycorp concentrates on the open market.

The Rhodia plant has operated for more than fifty years, although from 2000 to 2011, only four out of eighteen separation units were in use.⁴³ Since 2011, Rhodia has restarted the other separation units to process concentrates from mines like Mount Weld and Mountain Pass and also to recycle heavy rare earths from fluorescent lamps and magnets. The biggest constraint on recycling REEs has traditionally been the difficulty of collecting the waste products, but the increasing rate of collecting fluorescent lights to keep mercury out of landfills, especially in Europe, has made new recycling feedstock available.⁴⁴ The combination of recycling and expanded non-Chinese production of heavy rare earth concentrates alleviates some of the dependence on China even for heavy rare earths.

INNOVATION OUTSIDE OF CHINA

A final point of concern for many industry experts is that, because research and development (R&D) often collocates with production facilities, Chinese production of rare earth products could lead to Chinese technical dominance.⁴⁵ Presently, the downstream plants in China largely operate under licenses of foreign, especially Japanese, intellectual property. The Chinese government has made a major national commitment to rare earth research, with the Chinese Society of Rare Earths claiming tens of thousands of registered scientific and technical researchers as members (supposedly

compared to only a few dozen in the United States). Statistics counting Chinese researchers, scientists, and engineers, however, are notorious for including administrative staff and low-level technicians, making it easy to exaggerate Chinese prowess.⁴⁶

Far from Chinese technical dominance, the striking feature of recent developments in rare earth markets has been the continuation of U.S., European, and Japanese technological leadership. Molycorp's reopened mine and separation facility use a suite of new technologies that have increased the purity of extracted rare earth products, substantially reduced the environmental impact of the mining and chemical processing, and drastically lowered the cost of American production compared to the Mountain Pass operations that shut down in 2002.⁴⁷ Japanese companies are leading the way with new, low-dysprosium magnet technologies, and Rhodia in Europe has made tremendous progress in developing viable rare-earth recycling operations. In the current market, China looks like a technical laggard—for example, using old, environmentally destructive extraction technologies—rather than a technical leader.

Indeed Molycorp believes its new extraction process costs less than current Chinese production.⁴⁸ If so, even well-executed Chinese policy would not be able to carefully arrange Chinese export prices according to a “limit pricing strategy,” whereby Chinese companies would charge prices above the free-market price but just low enough to prevent entry by foreign competitors—a strategy that is often central to long-term market dominance. Further, the Chinese government suggests it is getting more serious about strengthening and enforcing environmental regulation of the Chinese rare earth industry, which will also raise its relative costs and hamper any limit-pricing strategy.⁴⁹

DOES ANY MARKET POWER REMAIN FOR CHINA?

Ultimately, however, even with these technological strides and with Molycorp and Lynas capacity emerging to produce rare earths outside of China, Chinese producers still supply at least 70 percent of the global market. That might be enough to enjoy some long-run market power, especially if the Chinese government succeeds in its plan to concentrate the Chinese industry in a handful of large companies that comply with regulations. Yet recent market dynamics show few hints of China using such power; instead, downstream consumers’ behavior seems to have driven market outcomes.⁵⁰

This leaves one area of lingering concern around REE supplies: the role of REEs in defense production, where market behavior is less relevant. The volumes used in defense production turn out to be relatively small.⁵¹ The percentage of total American consumption used in defense products differs from element to element, but for most rare earths, estimates put the number at well under 10 percent of U.S. demand—again, an amount that can probably be acquired through various methods of circumventing an embargo. Moreover, with U.S. production back in line at the Mountain Pass mine and factories in the United States producing at all stages of the supply chain, the U.S. defense market has much more flexibility today than it did at the low point between 2002 and 2009.

And perhaps more important, the defense market can probably accept some delays in delivery of rare earth components. Interruption of rare earth supplies will only have immediate effects on production if the supply chain does not include privately owned inventories; even under modern lean production strategies, most manufacturers and some brokers keep enough inventory on hand that can act as a partial shock absorber. And even if inventories are insufficient and a rare earth supply interruption knocks a weapons program off schedule, the defense acquisition system is used to schedule disruptions; disruptions often bring some financial costs, but for many reasons, they are a

sadly well-understood fact of life in defense.⁵² Moreover, a supply interruption cannot affect the existing weapons inventory. Unlike fears that Chinese electronics used in weapon systems might include Trojan horses or backdoors that would cede military advantage to the Chinese in a crisis, the rare earth magnets, lasers, and other technologies built into already-deployed American weapons would still work perfectly well even if those components had been imported from China and even if follow-on imports were interrupted. Thinking carefully through the disruption scenario, dependence on imported rare earth products brings less national security risk than originally feared.

Government Responses in the Rare Earths Market

Even as market adjustments have led the process of responding to rare earths shortages, governments have not stayed entirely on the sidelines. In most countries, the United States included, public opinion tends to support government action as appropriate when intended to protect national security. Overlaying this basic support for intervention on national security grounds, Americans in recent years have also grown particularly sensitive to China's growing power and budding rivalry with the United States.⁵³ Against this backdrop, it was unsurprising that, following the 2010 supply disruptions, bipartisan pressure to take action on rare earths quickly swelled in Congress, the Defense Department, the Department of Energy, and elsewhere across the U.S. government.

In contrast to this pressure within Congress and the executive branch, U.S. rare earth producers and industry leaders have been restrained in calls for policy intervention, limiting their wish lists to limited efforts such as a U.S. government-wide definition of strategic and critical materials, intended to ease interagency discussions of threats to the United States, and to "a strategic and critical minerals development fund."⁵⁴ Perhaps most surprisingly, apart from a few of the smallest, weakest suppliers, the majority of U.S. producers have hesitated to call for a broad government capital infusion into the rare earth industry.⁵⁵

Rather than subsidizing production, though, the Department of Energy in 2011 announced a series of competitions to support basic and applied research to find ways to use lower quantities of REEs in green energy products, totaling over \$150 million in investment.⁵⁶ These programs are a notable improvement over traditional U.S. patterns. The United States often struggles to make long-term investments of any kind, and in responding to crises, specifically energy-related crises, the United States often uses tax policy or subsidies to encourage production and installation of the current generation of technology.⁵⁷ In the past, this tendency has led to wasteful boom-and-bust cycles as the expanded capacity turns out to be uneconomic once the crisis passes and the subsidy is removed.⁵⁸ But in the frenzy over rare earths, the government has stuck to constructive, longer-range spending efforts.

Similarly, other consumer governments have not sat idle through the last few years. The Japanese government, especially through a government-backed agency called the Japan Oil, Gas, and Metals National Corporation (JOGMEC), has offered limited financial support to rare earth prospects in Vietnam, Kazakhstan, India, Mongolia, and Canada, a broad approach to diversifying supplies for a country that, unlike the United States, has no potential domestic sources.⁵⁹ In a bigger move in 2010, JOGMEC and a Japanese trading company called Sojitz loaned Lynas \$250 million in exchange for an agreement allowing Sojitz to purchase 8,500 metric tons per year of rare earth from Lynas for the next ten years.⁶⁰ These investments would surely be more controversial in the U.S. context, but thus far, they have aided rather than impeded the market response.

Just as China's entry into the rare earths business transformed the market in the 1990s, the capital investment and technological advances of the last decade are already transforming the market again, restoring competitive footing to non-Chinese producers and certainly undermining China's moment of near complete market dominance. In particular, the new U.S. government R&D investments should have fertile ground to build on, strengthening U.S. technological leadership in this important industry.

Conclusion

In the 2000s, the United States came to depend on China for its supply of rare earth materials, and American consumers came to expect the high performance that those imports allowed in defense systems, consumer electronics, and the growing green economy. Experts projected only further growth in demand for rare earths, so when China ratcheted down its export quota and tried to use its leverage in this market to put political pressure on Japan, pundits and politicians feared the worst.⁶¹ Conditions seemed ideal for China to earn extra-high profits and to compel foreign policy concessions. Supply was extremely concentrated in China, consumer demand seemed large and inelastic, substitute products appeared markedly inferior in quality and price terms, and consumption of critical intermediate goods was focused in a few countries that were specifically the ones China wanted to target with its foreign policy. Given so many structural factors in China's favor, it gained strikingly little for its efforts to exploit the rare earths industry in 2010. China may have won the immediate release of a fishing captain, but potential Chinese leverage dissipated rapidly thereafter.

REEs are no doubt important strategic materials, and for policymakers, China's alleged 2010 embargo marked an important new chapter in China's willingness to use its growing market strength to punctuate a geopolitical point. But the actual events that unfolded in the global REE market following the 2010 episode proved these initial concerns were just the newest entry in a long line of exaggerated fears and panics about leading economies' access to raw materials. Only a few years before rare earths dominated the headlines, U.S. policymakers' concerns focused on titanium imports from Russia.⁶² Other metals have been and will be on their agenda, too. And of course energy import dependence has traditionally generated the most worry, most often oil but also natural gas, especially in the context of Europe's dependence on imports from Russia. In each case, the fears have often been exaggerated.⁶³

The rare earths panic was an instructive test case. The broad lesson is that policymakers should not succumb to pressure to act too quickly or too expansively in the face of raw materials threats. Not all such threats are like that posed by the historical precedent that is typically invoked: the 1973 oil crisis. Then, the oil market dramatically changed in response to the Organization of the Petroleum Exporting Countries (OPEC) embargo, leading to sustained higher prices, because new sources of supply did not appear to undercut OPEC's dominance for nearly forty years.⁶⁴ But oil has for years been the exception; when people briefly feared that rare earths would make the oil experience more like the "new rule," their fears turned out to be largely misplaced.

Caution about overstating raw materials threats is particularly advisable because where foreign policy or intelligence analysts see a potential for dangerous market concentration and economic coercion, some businesses are also likely to see an opportunity to introduce competition and make a profit, ameliorating risks. Of course, strategic risks and market opportunities are rarely perfectly matched—some strategic risks may well be real, and market failures may sometimes require a government role in the response. The private sector is not omniscient, as seen in the downstream

industry's panic buying at the 2011 rare-earth price peak that led to losses. But businesses systematically try to take advantage of market opportunities like those provided by constrained supply. One happy side effect of those business incentives is that foreign policy pressure points naturally diminish. The global economy constantly moves and adjusts, investing in supply diversification and innovation to alleviate potential bottlenecks. Governments should gratefully accept the help.

Endnotes

1. For short reviews of the many uses of rare earth elements, see, for example, U.S. Department of Energy, *Critical Materials Strategy*, December, 2011; Donald I. Bleiwas and Joseph Gambogi, *Preliminary Estimates of the Quantities of Rare-Earth Elements Contained in Selected Products and in Imports of Semimanufactured Products to the United States*, 2010, U.S. Geological Survey Open-File Report 2013-1072, Reston, VA: U.S. Geological Survey, 2013.
2. For example, David Barboza, “China Says It Will Tighten Controls on Rare Earths,” *New York Times*, June 3, 2010, p. B8. The A1 stories really came in the fall of 2010, when China allegedly used a rare earths embargo to coerce Japan. See Martin Fackler and Ian Johnson, “Japan Retreats in Test of Wills with the Chinese,” *New York Times*, September 25, 2010, p. A1.
3. Katherine Bourzac, “The Rare-Earth Crisis,” *Technology Review*, April 2011; Paul Krugman, “Rare and Foolish,” *New York Times*, October 17, 2010.
4. Joseph Sternberg, “How the Great Rare-Earth Metals Crisis Vanished,” *Wall Street Journal*, January 8, 2014.
5. Ted Niles, “Western Rare Earth Discoveries May Just Feed China,” *Financial Post*, February 9, 2012.
6. James T. Areddy, “Rare-Earth Miner in U.S. Tackles China, Its Own Past,” *Wall Street Journal Online*, December 20, 2010.
7. Keith Bradsher, “China’s Plans for Mines Blocked,” *New York Times*, September 25, 2009, p. B4.
8. The GAO investigation led to publication of *Rare Earth Materials in the Defense Supply Chain*, GAO-10-617R, April 14, 2010.
9. Marc Humphries, “Rare Earth Elements: The Global Supply Chain,” Congressional Research Service, *Report for Congress*, R41347, June 8, 2012, pp. 19–20; Hiroko Tabuchi, “Block on Minerals Called Threat to Japan’s Economy,” *New York Times*, September 29, 2010, p. B1.
10. Fackler and Johnson, “Japan Retreats in Test of Wills.”
11. For example, Representative Mike Coffman (R-CO) has championed a series of bills to provide U.S. government assistance to the domestic rare earths industry; in introducing one of them in 2011, he drew the link from Chinese market power to proposed U.S. government response: “Not only has [China] ordered a reduction in exports of rare earth metals, but they have used their near monopoly status as leverage on unrelated issues. ... My bill ... calls for a comprehensive plan for research, development, demonstration, and commercial application to ensure the long-term, secure, and sustainable supply of rare earth materials for the United States. “Senator John Walsh (D-Montana) escalated the complaint in 2014: “The United States’ increasing reliance on foreign suppliers for rare earth and raw materials weakens both our economy and our national defense apparatus. ... It is reckless and inexcusable to use materials from China when we have them right here in the U.S. “See also, Humphries, “Rare Earth Elements,” which catalogs several much-discussed policy options.
12. Rhiannon Hoyle, “Corporate News: Rare Earths Succumb to Gravity,” *Wall Street Journal Asia*, November 14, 2012, p. 23; “The Astounding Rise of Western Rare Earth Extraction: Jack Lifton,” *Critical Metals Report*, September 18, 2012.
13. Daniel W. Drezner, “Bargaining, Enforcement, and Multilateral Sanctions: When Is Cooperation Counterproductive?” *International Organization* 54, no. 1 (Winter 2000), pp. 73–102.
14. “Molycorp Reports Second Quarter 2013 Results,” *Marketwatch*, August 8, 2013; “Lynas Plant Ramping Up,” *Kalgoorlie Miner*, April 25, 2013, p. 11; Rhiannon Hoyle, “Lynas Holds Back Rare-Earths Production,” *Wall Street Journal Online*, June 6, 2013.
15. Chuin-Wei Yap, “China Moves to Tighten Rare-Earths Control, Pave Way for Consolidation,” *Wall Street Journal*, January 3, 2014. The new consolidation effort follows a series of similar, failed efforts over the past decade.
16. Yajun Zhang, “China Considers Further Rare-Earth Quotas,” *Wall Street Journal Online*, December 29, 2010.
17. Keith Bradsher, “The Illegal Scramble for Rare Metals,” *New York Times*, December 30, 2010, p. B1; Keith Bradsher, “China Seizes Rare Earth Mine Areas,” *New York Times*, January 21, 2011, p. B1.
18. Ting and Seaman, “Rare Earths: Future Elements of Conflict in Asia,” p. 239.
19. Stringer, “China’s Rare Earth Toxic Time Bomb.” For discussion of similar state capacity constraints on economic statecraft, see Adam Stulberg, *Well-Oiled Diplomacy: Strategic Manipulation and Russia’s Energy Statecraft in Eurasia* (Albany: State University of New York Press, 2007).
20. U.S. Department of Energy, *Critical Materials Strategy*, pp. 17–19; Gerald Parkinson, “Challenges for U.S. Petroleum Refiners,” *Chemical Engineering Direct*, May 15, 2012.
21. Nayantara Hensel, “Economic Challenges in the Clean Energy Supply Chain: The Market for Rare Earth Minerals and Other Critical Inputs,” *Business Economics*, Vol. 46, No. 3 (September 2011), p. 173.

22. See Dudley Kingsnorth's related comments about China's dwindling ability to pressure downstream manufacturing to move to China, quoted in Bradsher, "Chasing Rare Earths."

23. For an accessible summary of the process, see Cindy Hurst, "China's Rare Earth Elements Industry: What Can the West Learn?" Institute for the Analysis of Global Security, March 2010, pp. 4–5.

24. David Merriman, "A Review of the Global Supply of Rare Earths," Presentation to the Royal Society of Chemistry Environmental Chemistry Group, March 20, 2013; Dudley Kingsnorth, "Meeting the Challenges of Supply This Decade," Presentation at the Environmental and Energy Study Institute, Washington, DC, March, 2011; U.S. Department of Energy, *Critical Materials Strategy*, p. 81.

25. "Lynas Triples Production," *Kalgoorlie Miner*, January 9, 2014, p. 10.

26. Bleiwas and Gambogi, "Preliminary Estimates," pp. 3–4.

27. "Molycorp Announces Startup of Its Heavy Rare Earth Concentrates Facilities at Mountain Pass," *Mining Engineering*, October 1, 2012.

28. U.S. Department of Energy, *Critical Materials Strategy*; U.S. Undersecretary of Defense for Acquisition, Technology, and Logistics, *Report to Congress: Rare Earth Materials in Defense Applications*, March 2012, p. 4.

29. Adam Brown, Simon Müller, and Zuzana Dobrotkova, *Renewable Energy: Markets and Prospects by Technology*, International Energy Agency Information Paper, November 2011, pp. 49–56.

30. Bleiwas and Gambogi, "Preliminary Estimates," pp. 8–11; U.S. Department of Energy, *Critical Materials Strategy*, pp. 22, 91–92, 106–108.

31. "Hitachi Metals Reduces Rare-Earth Dysprosium in Electric-Motor Magnets," *Automotive Engineering Online*, April 5, 2013; John Kell, "Molycorp in Venture for Japan Facility," *Wall Street Journal*, November 30, 2011; Jim Witkin, "A Push to Make Motors with Fewer Rare Earths," *New York Times*, April 22, 2012, p. AU2. Other magnet manufacturers like Shin Etsu and Vacuumschmelze make similar products.

32. The samarium-cobalt magnets offer high strength and even higher temperature operations than the neodymium magnets but at small penalties in weight and brittleness (relative to the high-temperature versions of the neodymium magnets). In some cases, downstream manufacturers are also switching to traditional iron magnets or adding cooling systems to their products to enable use of low-dysprosium versions of neodymium magnets.

33. See also David Fickling, "Rare Earths Seen Growing Less Rare," *Wall Street Journal Online*, May 6, 2011.

34. James T. Areddy, "China Still Dominates Rare Earth Processing," *Wall Street Journal*, December 5, 2013.

35. U.S. Department of Energy, *Critical Materials Strategy*, pp. 14–19.

36. Humphries, "Rare Earth Elements," p. 8; Binnemans et al., "Recycling of Rare Earths," p. 4.

37. "Molycorp Climbs as Goldman Analyst Says Distribution Deal May Ease Cerium Capacity Concerns," *Associated Press Newswires*, March 15, 2013.

38. Keith Bradsher, "Chasing Rare Earths," *New York Times*, August 25, 2011, p. B1. Specifically, producing magnets requires reduction of the oxides into rare earth metals followed by alloying, then forming the alloys into magnets shaped for particular end uses, and finally making the actual product such as a generator in a wind turbine or a motor in a disk drive or hybrid-electric vehicle.

39. Mark Smith. Statement to the House, Subcommittee on Investigations and Oversight and Committee on Science and Technology, "Rare Earth Minerals and 21st Century Industry" 111th Congress, March 16, 2010.; U.S. Government Accountability Office, "Rare Earth Materials," slide 19; Howard Schneider, "China's Advantage Erodes in a Key Area: Rare Earth Minerals," *Washington Post.com*, October 27, 2012; *Hitachi Metals, Ltd. and Hitachi Metals North Carolina, Ltd.'s Complaint under Section 337 of the Tariff Act of 1930, As Amended*, U.S. International Trade Commission, August 10, 2012, pp. 3, 5.

40. Merriman, "Review of the Global Supply;" Alain Rollat, "How to Satisfy the Rare Earths Demand: Rhodia Rare Earth Systems Initiatives," Presentation to the Société Européenne des Ingénieurs et des Industriels, September 28, 2012, p. 13.

41. James T. Areddy, "Deal Shows China's Sway in Rare-Earth Minerals," *Wall Street Journal Online*, March 11, 2012.

42. Ray Brindal, "Lynas Rare Earths Contract Extended to 10 Years," *The Australian*, January 21, 2010.

43. Rollat, "How to Satisfy Rare Earths Demand."

44. Elaine Burridge, "ICIS Innovation Award 2012: Closing the Loop on Rare Earths," *ICIS Chemical Business*, October 19, 2012; Koen Binnemans, Peter Tom Jones, Bart Blanpain, Tom Van Gerven, Yongxiang Yang, Allan Watson, Matthias Buchert, "Recycling of Rare Earths: A Critical Review," *Journal of Cleaner Production*, Vol. 51 (2013), pp. 1–22.

45. Mark Smith testimony; Cindy A. Hurst, "China's Ace in the Hole: Rare Earth Elements," *Joint Forces Quarterly*, Issue 59 (4th Quarter, 2010), pp. 121–26.

46. Hurst, "China's Ace in the Hole," Notes the administrative personnel included in the membership numbers. More broadly, see Tai Ming Cheung, "The Chinese Defense Economy's Long March from Imitation to Innovation," *Journal of Strategic Studies* 34, no. 3 (June 2011), pp. 335–38; Vivek Wadhwa, Gary Gereffi, Ben Rissing, and Ryan Ong, "Where the Engineers Are," *Issues in Science and Technology* (Spring 2007).

47. For a list of key innovations, see <http://www.molycorp.com/technology/molycorp-innovations>.

48. For a review of other U.S. inventions currently in the process of commercial scale-up, see “The Astounding Rise of Western Rare Earth Extraction.”

49. David Stringer, “China’s Rare Earth Toxic Time Bomb to Spur Mining Boom,” *Bloomberg*, June 4, 2014.

50. Author interviews with rare earth traders, Tokyo, March 2014.

51. U.S. Undersecretary of Defense for Acquisition, Technology, and Logistics, *Report to Congress: Rare Earth Materials in Defense Applications*, March, 2012, p. 1; Hurst, “China’s Ace,” p. 124.

52. Harvey M. Sapolsky, Eugene Gholz, and Caitlin Talmadge, *U.S. Defense Politics: The Origins of Security Policy*, 2nd edition (New York: Routledge, 2013), chapter 8.

53. “As New Dangers Loom, More Think the U.S. Does ‘Too Little’ to Solve World Problems,” *Pew Research Center*, August 28, 2014. <http://www.people-press.org/files/2014/08/8-28-14-Obama-and-Foreign-Affairs-release.pdf>.

54. See, for example, Jeffery A. Green, Testimony before the U.S.-China Economic and Security Review Commission, Hearing on China’s Global Quest for Resources and Implications for the United States, January 26, 2012. For a similar recommendation that steps to the brink but does not recommend industrial policy responses to a government-wide critical materials definition, see Christine Parthemore, Testimony before the House Committee on Foreign Affairs Subcommittee on Asia and the Pacific, September 21, 2011.

55. For example, Mark Smith testimony. See also Jim Snyder, “Rare-Earths Producer Molycorp, Rivals Lobby Congress,” *Bloomberg*, January 14, 2011. On the other hand, some Congressional Representatives and Senators continue to introduce bills to try to help the rare earths industry. Mark Halper, “Senate Bill Would Slash U.S. Reliance on China for Vital Metals While Also Securing an Energy Future,” *SmartPlanet Bulletin*, February 11, 2014.

56. “DOE to Set Up Energy Innovation Hub; Ames Laboratory Will Establish Critical Materials Institute,” *Mining Engineering*, February 1, 2013; “Energy and Clean Technology Alert: ARPA-E Launches Five New Programs with \$130 Million in Funding,” *Mondaq Business Briefing*, May 9, 2011.

57. Richard R. Nelson, “The Simple Economics of Basic Scientific Research,” *Journal of Political Economy* 67, no. 3 (1959), pp. 297–306; Linda R. Cohen and Roger G. Noll, eds., *The Technology Pork Barrel* (Washington: Brookings Institution, 1991).

58. David Victor and Kassia Yanosek, “The Crisis in Clean Energy,” *Foreign Affairs* 90, no. 4 (July/August, 2011), pp. 112–20.

59. Daisuke Segawa, “Sojitz to Buy Australian Rare Earths / Imports Likely to be Limited Initially, so China Will Continue to be Main Source,” *Daily Yomiuri*, August 22, 2011.

60. Hiroko Tabuchi, “The Hunt for Rare Earths,” *New York Times*, November 25, 2010, p. B3.

61. For example, Tom Ashbrook’s questioning during the “Rare Earth Elements, Global Power & The China Dynamic” episode of his National Public Radio show, *On Point*, October 4, 2010. <http://onpoint.wbur.org/2010/10/04/rare-earth-minerals>.

62. U.S. General Accountability Office, *Defense Suppliers: Factors Affecting U.S. Titanium Aircraft Component Manufacturers’ Market Share of DoD Business*, July, 2013; Doug Cameron and Arkady Ostrovsky, “Aerospace Sector Fears Titanium Squeeze,” *Financial Times*, February 20, 2006, p. 24.

63. Eugene Gholz and Daryl G. Press, “Energy Alarmism: The Myths that Make Americans Worry about Oil,” *Cato Institute Policy Analysis* (April 2007); Blake Clayton and Michael Levi, “The Surprising Sources of Oil’s Influence,” *Survival* 54, no. 6 (December 2012-January 2013), pp. 107–20.

64. Michael Levi, *The Power Surge: Energy, Opportunity, and the Battle for America’s Future*, New York: Oxford University Press, 2013.

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