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Global political economy of rare earths: changing positions of major market actors including China, European Union, Japan and United States

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Abstract: The availability of rare earth elements became a global concern in 2010 when prices soared after China restricted exports of these metals. What measures can or should states or companies adopt to secure a supply of certain scarce resources where the control of the supply is dominated by only a few nations? This problem is becoming increasingly urgent in the case of rare earths because the global demand for these minerals continues to increase. We investigated the policy measures that countries that are major consumers of rare earths have taken when facing supply disruptions, including China, the European Union, Japan, and the United States. We found that strengthening research and development (R&D) and innovation became the first choice of these countries; in addition, market solutions helped to mitigate the supply risk. The supply disruption caused by China's restrictions on the export of rare earths in 2010 dissipated a year later; this was caused by recycling and more efficient use of these metals and by initial steps to create new sources or alternative products. This event illustrates that both R&D and innovation are the most important elements related to industrial success rather than administrative interventions.

1. Introduction

Rare earth elements (REEs) are widely used in various types of equipment and fields such as in the production of social networking devices, electrical vehicles, wind energy, computers, smart phones, and equipment used in the military and for national defense^[2]. The global demand for REEs increased from 79,000 to 145,000 metric tons (mt) between 2000 and 2015. Demand is expected to increase to 200,000 mt by 2020 as the world moves to a green future^[6]. China accounted for around 95% of the global production of REEs between 2000 and 2012, a figure that had decreased to about 85% in 2015.

China developed its rare earth industry through policies that provided subsidies and export rebates in the mid-1980s. Favored by those subsidies as well as by inexpensive labor costs and a lax environmental framework, China gained a dominant position in the global rare earth market. However, in order to protect the country's future domestic supply, address environmental concerns and increase prices, China implemented export quotas on rare earths in the early 2000s. China precipitated a "rare earth supply crisis" by slashing its rare earth export quotas by about 40% in 2010. This policy caused



wide concern in the major consumer countries and created concerns about the stability of rare earth supplies. Against this backdrop, the countries that are most dependent of REEs — primarily Japan, the US and the European Union (EU) — took steps to secure access to sources of rare earth materials^[7].

These countries mainly focused their efforts on strengthening research and development (R&D) and innovation in an effort to find ways to reduce or eliminate the use of REEs in downstream applications and to increase recycling, rather than to provide subsidies for rare earth production. Simultaneously, market responses mitigated the crisis because non-Chinese suppliers began to produce REEs, manufacturers found ways to use smaller amounts of REEs, and high-tech companies increasingly invested in new recycling methods. All of these steps contributed to a significant decrease in demand. Next, speculators realized that the actual demand for REEs was lower than they had expected and prices plunged on the global market. In fact, the global rare earth market has been suffering from an extended buyer's market since 2011.

This paper analyzes the global political economy of rare earths, focusing on the four major players/countries listed above. Next, it highlights the implications for China, and concludes with a discussion of how we can understand and respond to this resource supply crisis.

2. Rare earth elements: background

2.1. Rare earth elements

The rare earth supply crisis of 2010 awakened awareness of the importance of REEs globally. Policymakers, industry executives and citizens realized that China had cornered the REE supply. For many people, the crisis was their first introduction to the issue of rare minerals, fueled by the news of an alleged Chinese embargo on REE exports and rising concerns over potential supply disruptions.

As of 2016, the US Geological Survey (USGS) evaluated the world's rare earth reserves to be about 130 million metric tons^[12]. China currently has the largest share of world's rare earth reserves (42.3%) and the US has only about 1.4%. Other reserves are mainly located in Australia, Brazil, India and Russia.^[11] New deposits are sometimes discovered, but few of these can be developed into actual mines because of the high fixed costs involved and related environment issues.

2.2. Rare earth supply

China still has a monopoly on rare earth production. Of the global production of about 123,000 tons of rare earth oxides (REOs) in 2014, 85% came from China. Although the market for REEs is relatively small, the REE market attracted hundreds of companies around the world when prices surged in 2010. The major companies, such as Molycorp in the US and Lynas in Australia, started delivering REEs to the world market in 2011 and 2012, respectively. Other projects were ongoing in Brazil, Canada, Greenland, South Africa, and the United States. However, given the size of the global market for REEs and the cost of mining, it is unlikely that more than only a handful of projects can develop into actual production in the next one or two decades because of the size of the investment required to begin mining.

2.3. Rare earth demand

Rare earths are used in products that people use for everyday activities around the world. And LREEs are more widely used than HREEs, but the latter remain very important in several industries (e.g. magnets, phosphor and ceramics). In any case, total REE consumption has grown little in the last several years because of more frugal use by manufacturers.

Looking forward, however, the demand for rare earth is projected to increase considerably in the coming years. The use of REEs in the personal technological device sector (e.g., smart phones or computers) and in support of the production of green energy is expected to grow significantly in the coming years. The production of hybrid and electric vehicles, magnets and batteries as well as wind energy production require large amounts of REEs. Consequently, REE consumption is expected to grow. In addition, a recovering world economy will also contribute to higher REE demand.

3. The political economy of rare earths: four major players

Advanced technology, such as is used in communication, commerce, and military applications, makes wide use of REEs. Therefore, REEs are recognized to be a strategic commodity that can ensure a country's economic prosperity and security.

The REE supply crisis provided an interesting case of international market disruption, and governments and market actors experienced quite divergent reactions. This crisis offered a window of opportunity for scholars and policymakers to overcome traditional attitudes regarding resources and energy crises, allowing them to search for new perspectives that would help them to address challenges brought on by future crises that we can expect in this area.

3.1. China

China has abundant REE reserves and does not face any short-term supply disruptions. It could face a shortage in the distant future, however, caused by rapid resource depletion and high rates of production. Chinese policymakers feel that China can no longer bear the costs of meeting both domestic and global demand of REEs^[4]. The Chinese government consequently restricted REE production and exports with the goals of consolidating the domestic REE industry, slowing resource depletion, avoiding future supply disruption and protecting the environment. However, these measures caused political uncertainty related to the supply of REE as well as caused a dramatic increase in prices between mid-2010 and mid-2011.

All major REE enterprises in China reaped high benefits from the increases in prices, but this also adversely affected the domestic end-users such as application manufacturers. For example, the prices of HREEs used for producing red triphosphor powder that is used to produce fluorescent lightbulbs increased by more than ten times, the costs of raw materials for high-quality permanent magnets using neodymium and dysprosium rose by nearly eight times, and the input costs for polishing material increased by more than seven and a half times from January to mid-2011. The resulting higher costs caused prices of products to rise sharply^[1]. The products now require smaller amounts of REEs or producers have adopted new techniques to avoid the use of REEs altogether. For example, LED lamps with a longer life time replaced fluorescent lamps that require HREEs; LEDs only contain about 1% of the phosphors needed in a fluorescent lamp with an equivalent lighting efficiency; hydrogen storage production declined significantly due to weakened demand for nickel-metal hydride batteries and the rising market share of lithium-ion batteries^[5]. Thus, although the prices of REEs fell again after 2011, the demand for REEs had declined creating new concerns related to oversupply.

On 31 December 2014, China's Ministry of Commerce announced that it would abolish export quotas on REEs in 2015, which was completed on 1 January 2015. This statement essentially marked the end of the World Trade Organization lawsuit launched by the US, the EU, Japan and others in March 2012 challenging China's export restrictions of REEs^[13]. Meanwhile, the Chinese government abolished export duties on REEs in 1 May 2015. This fueled a 25% increase in REE exports in 2015. Simultaneously, China's announced plans to establish six new REE corporations by June 2016. This measure aims to improve control over China's domestic REE production and deliveries as well as to reduce the role of the black market, eventually leading to rising prices for REEs.

3.2. Japan

On 7 September 2010, a Japanese Coast Guard crew detained a Chinese fishing boat captain whose vessel had collided with a Japanese coast guard boat and took the captain to Japan. The Chinese government strongly protested. On September 25, Japan ultimately released the captain after 18 days in detention. After that, the relationship between China and Japan sank to a low point. Many Japanese enterprises claimed that China suspended shipment of REEs to Japan but the Chinese Ministry of Commerce denied those allegations. Meanwhile, the annual China-Japan exchange meeting on REEs that had been held for 21 years was canceled in 2010. These actions led to widespread concern and fears about the REE supply within the Japanese government and related business executives.

Japan heavily depends on the export of high-tech products that require a large amount of REEs (e.g.

electronics and cars). Meanwhile, Japan has no REE reserves itself, and depends almost entirely on China for its supply. Thus, the disruption of the REE supply shocked the Japanese economy, and was considered a new security risk to Japan.

In response to the Chinese regulations, the Japanese government initiated a number of measures to decrease dependency on China's supply of REEs. The independent administrative institution known as Japan Oil, Gas and Metals National Corporation (JOGMEC), established in 2004 when the former Metal Mining Agency of Japan merged with the former Japan National Oil Corporation, invested in new rare earth projects with foreign companies. In March 2010, JOGMEC entered into a memorandum of agreement for REEs with a Canadian exploration company in the Ytterby region in Canada that possesses rich HREE reserves. In 2011, JOGMEC and the Japanese company Sojitz provided USD 250 million for the development of the Lynas mine in Australia. They expect to receive about 8,500 metric tons per annum of REEs for a period of ten years. JOGMEC also conducted REE explorations in Malawi in 2016.

However, investing in new mine development seems to be a high-risk strategy. The basic payback period can be very long and depends on an inherently uncertain future demand. The demand for REEs has fluctuated in part because of changing technologies. After the 2010 supply crisis, falling REE prices made new investments in mining less attractive. All of the above projects except Lynas were unable to develop into actual production, and Lynas is struggling to become profitable.

Aside from investing in new REE mines, the Japanese government and firms are actively looking for ways to reduce the amount of REEs needed, to recover REEs from discarded electronics, and to develop new technologies to substitute for REEs. Hitachi, a Japanese enterprise, announced in 2012 that it had developed an industrial 11 Kw permanent magnet motor without using rare earth metals. Honda succeeded in recovering rare earth metals from used nickel-metal hydride batteries. JOGMEC invented a process to recycle used glass polish and discarded phosphor containing REE materials (JOGMEC, 2012). Those efforts are reshaping Japan's future REE demand.

With the concerted efforts of government and the private sector, Japanese REE consumption rapidly declined between 2007 and 2012 from 34,700 to 22,075 tons. Japan successfully decreased its dependence on China's rare earth exports, and China's share of Japan's rare earth imports declined between 2008 and 2015 from 90 to 53%.

3.3. The United States

In the US, the rare earth supply disruption of 2010 also prompted Congress, the Department of Defense, the Department of Energy (DOE) and other US governmental agencies to take action. For example, the DOE released its "*Critical Materials Strategy*" report in 2010 predicting a possible shortage of five REEs in the medium term (2015–2025) with the growing development of clean energy (US DOE, 2010). The US National Defense Authorization Act for Fiscal Year 2010 requested the Government Accountability Office (GAO) to examine the role of rare earths in the defense supply chain in 2010. In 2012, the Congressional Research Service presented a report to Congress declaring that REEs are critical to many advanced weapons systems and related equipment^{[3][9]}

To combat a potential shortage of REEs and other metals such as lithium, in 2013 the DOE announced it would provide federal funding of up to USD 120 million over five years to the Critical Materials Institute (CMI), led by the Ames Laboratory. The CMI has developed over 30 projects in four areas, such as the development of strong permanent magnets with reduced REE content and new efficient phosphors without critical material content; the CMI also worked on recovering REEs and uranium from phosphate ore processing and the reuse and recycling of REE magnets. The CMI had added ten new industrial and research affiliates to its research programs by April 2016^[8].

The DOE has also explored new technologies to address and disruption in the REE supply. It announced funding for ten projects in December 2015 for research on the recovery of REEs from coal and coal by-products.

Unlike Japan, the US has rich REE reserves. This provides more choices for investors, producers and the government. Molycorp, an American rare earth producer, re-opened its Mountain Pass mine in

2012. Two other US companies are also considering future production. Ucore Rare Metals owns the Bokan Mountain deposit in southern Alaska and that deposit has the highest grade HREEs in the US. Another company, Rare Element Resources, owns a large site in Bear Lodge, Wyoming; Rare Element Resources is working on detail engineering plans for their future mine. However, as REEs prices fell in recent years, the prospects for these projects are not good and Molycorp even closed its mine in 2015.

The supply crisis has had limited effect on the US REE market. US REE consumption increased to 15,000 metric tons in 2012 after a short decline in 2011. Since then, with the concerted effort to boost R&D and innovation, the US has mostly focused on strengthening its future REE supply chain, and less so on reducing its level of consumption.

3.4. European Union

European demand for REEs is not as high when compared with that of the US or Japan. EU consumption was 8,050 metric tons of REO in 2010. The effect of the REE supply crisis on Europe's economy and military is therefore smaller than that in Japan or the US. However, the demand for REEs in the EU is predicted to rise in the near future. Moreover, because the EU currently has no rare earth producer, a major shortage could have devastating effects on the EU economy. In a bid to strengthen its rare earth supply chain security, the EU has taken related political and economic measures.

Together with the US and Japan, the EU initiated a World Trade Organization dispute settlement against China's export policies related to REEs in March 2012. This case ultimately helped to solve the issue in January 2015 when China loosened its export restrictions. Next, the EU released a "list of critical raw materials" in 2013, identifying 20 critical raw materials based on their economic importance and supply risk. REEs were split into HREEs, LREEs and scandium. HREEs and LREEs are listed as critical materials with the highest and the second highest supply risk, respectively.

Furthermore, the EU is actively cooperating with the US and Japan on research and education related to critical raw materials and their uses in emerging technologies. The EU has organized four US-Japan-EU trilateral conferences on critical raw materials since 2011 in collaboration with the US DOE, Japan's Ministry of Economy, Trade and Industry and the Japanese New Energy and Industrial Technology Development Organization.

Soaring rare earth prices resulted in intensified public and private investment in the exploration of REE deposits in Europe. Several REE deposits were identified in Greenland and the Nordic countries. The best known of these are the Norra Karr deposit in Sweden and the Kvanefjeld deposit in Greenland. Norra Karr (owned by Tasman Metals, Ltd.) is a large HREE deposit located in south-central Sweden. The EU's preliminary Economic Assessment was completed in 2012 and identified a reserve of 59 million metric tons of HREEs. The Kvanefjeld deposit lies in southern Greenland and is currently being explored by Greenland Minerals and Energy, Ltd. Environmental issues related to radioactive waste as well as to REE production and transport are probably the largest hurdles for exploration while current low prices will make it very difficult to obtain finance support.

Europe is currently increasing its cooperation with the US, Japan, Australia and Canada to jointly develop an alternative supply chain and to establish knowledge and technology transfers^[10]. These measures could help the EU to gain the funding and expertise it needs to develop REE sources, and decrease Europe's rising demand for REEs.

4. The implications for China

The Chinese government announced export restrictions on REEs; in addition, its new six corporation framework for REEs will help to control environmental impacts and smuggling as well as to force consolidation of small-scale mining operations into larger companies in 2010. These policy measures, to a certain degree, addressed the problem of rapid resource depletion. However, the downstream plants in China largely operate under licenses of foreign intellectual property. Foreign companies from Japan, the US and EU control the essential patents for rare earth products. Japan has filed about 53%

of global patents for rare earth permanent magnet materials; meanwhile, the US has 16% while China only has 10%. Similar percentages apply to other semi-finished applications. Further up the rare earth supply chain, foreign companies also control most of the patents, such as those related to hard drives and other electronic components.

The huge technology gap between Chinese and foreign manufacturers of semi-finished and final products has resulted in the low international competitiveness of many Chinese products. China has to import high-value products or purchase the patents from Japan or other countries. Those producers of high-value semi-finished products suffered less than low-value upstream segment during the supply crisis. In turn, the rare earth enterprises in China suffered more than those in other countries which offer high-value or end-use products. Because the prices fell to their lowest point since 2011, rare earth enterprises in China generally have been operating with minimal profits or have had operating deficits. Some producers stopped or markedly slowed production, while no significant breakthroughs developed in the pattern of final consumption during the current decade.

While China adopted a planned economic system to design and manage the REE market, Japan, the US and EU strengthened their R&D efforts to improve rare earth use efficiency and recycling as well as to find substitutes for REEs. The US DOE subsidized research for the recycling of REEs from coal and its by-products. Japanese enterprises are leading the way in low-dysprosium magnet technologies. The French chemical company Rhodia has made tremendous progress in developing viable rare earth recycling operations. Compared with these countries, the research and development operations of Chinese enterprises have been quite limited with weak cooperation between industry and science and an inefficient use of R&D funds. In addition, cooperation between the US, Japan, Australia and the EU is tending to marginalize and isolate China. This will also aggravate the technology gap in environmental-friendly resource extraction, separation technologies, recycling and substitutes for rare earth metals between China and other industrialized nations.

It therefore seems more important for China to improve its innovation capability than to control production and export quotas. This includes an increase in R&D expenses as well as the exploitation of new applications, the creation of new tax exemptions and subsidies for high-technology enterprises, with the goal of ultimately increasing the competitiveness of REE downstream and end-use sectors. Meanwhile, investments in effective substitutes and recycling processes should help decrease China's strongly rising demand for REEs and prolong the service life of rare earth deposits thereby avoiding potential future shortages. Moreover, by enhancing international cooperation with the US, Japan, EU, Australia and South Korea, China could increase its ability to innovate and develop new technology.

5. Conclusion

REEs are no doubt important strategic materials related to consumer electronics, defense systems and the growing green economy. In the early 2000s, the world became to heavily dependent on China for its supply of REEs. As the world moves to a greener and cleaner future, experts project that the demand for REEs will grow in the near future. When China suddenly decreased its export quota in 2010, policymakers and pundits feared acute supply shortages of REEs and the "rare earth supply crisis" became a topic of extreme interest globally.

Downstream users stockpiled REEs to protect themselves from future disruptions and speculators invested in many small mining companies that promised to develop new sources of REEs worldwide (Gholz, 2014). REE prices soared again in late 2010.

In order to avoid shortages and secure future access to rare earths, major consumer countries such as Japan, the US and the EU have started to develop substitutes for rare earths, to improve the resource use efficiency and increase recycling rates. Meanwhile, major mining companies such as Lynas and Molycorp have started production that reduced China's dominant share in the global output of REEs.

Many downstream users found effective ways to decrease the amounts of REEs they used. They also developed substitutes for the use of REEs in high-technology products and recycled rare earth metals from many applications. These market actions effectively reduced overall demand and mitigated the shortage. However, the fixed costs of mining are astronomically high making it difficult

for new producers to enter the market, especially with the current low REE prices. Therefore, resource efficiency and innovative recycling efforts will be the major market changers.

The rare earths crisis case offers lessons for policymakers and business leaders leading up to the next raw material crisis. States or companies should not succumb to fear or political pressure and act too rapidly. They should explore alternative courses of action including investing in R&D and innovation to increase resource use efficiency that will support the continuing evolution of the resource markets and will alleviate potential bottlenecks in the economic system.

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