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ABSTRACT

Rare earth elements (REEs) have become increasingly important because of their relative scarcity and worldwide increasing demand, as well as China's quasi-monopoly of this market. REEs are virtually not substitutable, and they are essential for a variety of high-tech products and modern key technologies. This has raised serious concerns that China will misuse its dominant position to set export quotas in order to maximize its own profits at the expense of other rare earth user industries (wealth transfer motive). In fact, export restrictions on REEs were the catalyst for the U.S. to lodge a formal complaint against China in 2012 at the WTO. This paper analyzes possible wealth transfer effects by focusing on export quota announcements (so-called MOFCOM announcements) by China, and the share price reactions of Chinese REE suppliers, U.S. REE users, and the rest of the world REE refiners. Overall, we find limited support for the view of a wealth transfer in connection with MOFCOM announcements only when disentangling events prior to and post the initiation of the WTO trial, consistent with the trial triggering changes to China's REE policy and recent announcement to abolish quotas. We do find, however, that extreme REE price movements have a first order effect on all companies in the REE industry consistent with recent market trends to enable hedging against REE price volatility.

JEL Classification: F13, F52, G14, Q31, Q34, Q37, Q38

Keywords: Announcement Effects, Event Study, Rare Earths Elements, WTO

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“There is oil in the Middle East; there is rare earth in China...” (Deng Xiaoping, 1992)¹

“In the beginning of the 1980s, we sold REE at the price of salt. But they deserve the price of gold. We are just starting to protect our natural interests.” (Wen Jiabao, 2010)²

1. Introduction

The economic importance of rare earth elements (REEs) has been on the rise recently because of increasing demand and their relative scarcity. REEs are essential for many of today’s most important high-tech products and technologies, such as photovoltaic cells, wind energy turbines, hydrogen purification systems, heat pumps, hybrid and electric cars, mobile phones, camera lenses, fiber optics, displays, and other computer equipment because of their magnetic, optical, and electronic properties.

The global rare earth mining market currently stands at approximately U.S. \$1 billion per year, and it is expected to continue to experience rapid growth (Massachusetts Institute of Technology’s Energy Initiative, 2010). At present, however, China is the main producer of REEs, controlling about 97% of the market and about 75% of the economically important end use components (see Monahan, 2012, and Figures 1 and 2). Moreover, China has the power to impose duties on exports, by, e.g., setting export quotas. This has led to serious industry concerns and fears in the U.S. and other foreign countries. REEs have also experienced alarmingly volatile price shifts, with the prices of some elements increasing by a factor of more than 10 (see KNCV, 2012, and Figure 3).

— Please insert Figure 1, 2 and 3 about here —

The U.S. depends heavily on REE imports from China. In 2010, for example, over 80% of imported REEs in the U.S. came from China (see Figure 4). As a result, the U.S. Congress is currently considering several bills to evaluate the vulnerability of the U.S. commercial and

¹ Deng Xiaoping was the “de facto leader” in China from 1979-1997. See Baotou National Rare Earth Hi-Tech Industrial Development Zone (2013).

² Premier of the State Council of China, 2003-2013.

defense industry to REE supply shortages as well as to any sharp price increases (shocks). Morrison and Tang (2012) found that increasing REE prices would “undermine the global competitiveness of many U.S. firms (lowering their production and employment), impede technological innovation, and raise prices for U.S. consumers.”

— *Please insert Figure 4 about here* —

Those fears came true in several industries, such as the multibillion dollar hard disk drive industry, at the beginning of 2011, when prices for crucial REEs experienced rapid increases (see Figure 3). U.S. manufacturers Seagate and Western Digital, who produce components for personal computers, storage servers, smartphones, etc., had to accept significantly higher production costs due to higher REE prices. Monahan (2012) estimates that the increase in REE prices from July 2011 to September 2011 reduced Seagate’s and Western Digital’s net income by 37% and 21%, respectively. Shortages in the elements europium and terbium also negatively affected the production of energy-efficient lamps and displays, because no substitutes were available. Another element for which shortages have been recorded is lanthanum, which is essential for petroleum cracking catalysts and refining (see KNCV, 2012).

The Chinese government was able to establish its dominant position because it not only controls the vast majority of the world’s extracted REEs, but it skillfully put into place a policy to impact the institutional as well as the meso- and macroeconomic environments of this market (Pitelis, 2013). The inability of manufacturing companies to find effective REE substitutes, and the lack of financial markets on which to buy financial instruments for hedging purposes, also contributed to the impasse.

The situation is not comparable for Chinese REE users, such as manufacturing companies, because the Chinese government implemented a dual-pricing policy for the most important REEs, such as cerium and neodymium. Within this system, prices of exported REEs are much higher than prices for the same elements used by Chinese companies. This ultimately created

a kind of crowding-out effect for foreign companies (see Figure 3), who can only purchase REEs at lower prices by forming joint ventures with Chinese companies. They are then required to contribute the necessary technology, key equipment, and capital. This technology transfer, in exchange for access to the Chinese market, was at the heart of China's ostensible open door policy, begun in the late 1970s-early 1980s under Deng Xiaoping (Velasquez, 2009). However, the joint venture structure brings with it a tremendous risk of technology tunneling for foreign companies.

Several governments, including the U.S., Japan, and the EU, have complained that China was strategically setting export quotas on REEs in order to foster their own domestic economic development. These countries brought a dispute resolution case against China to the World Trade Organization (WTO). This paper aims to determine the strategic importance of the Chinese export quota policy (so-called MOFCOM announcements, which were also addressed at the WTO trial) by exploring whether shareholder wealth is transferred from U.S. companies who use REEs in production to Chinese REE supplier companies. We argue that this setting is particularly suitable for addressing the research question, because the U.S. is the leading consumer of REEs and imports almost the entire amount of REEs from China.

We proceed in two steps. First, we use an event study to analyze value changes for shareholders of U.S. user and global REE supplier and refiner companies and for Chinese REE supplier companies in response to extreme REE price increases and decreases. This analysis demonstrates how REE price changes translate into stock price movements of REE-related companies.

In a subsequent analysis, we run event studies to compute the cumulative abnormal returns (*CARs*) of listed companies in the REE consumer and processing industry and REE suppliers in China in response to the first thirteen MOFCOM announcements for various event windows. We examine the cross-sectional determinants of these *CARs* to analyze *relative* wealth transfer effects from U.S. REE users and global REE supplier and refiner companies to

Chinese REE suppliers in a multivariate regression framework. If the export quotas are set to maximize the profits of the Chinese rare earth industry, we expect to find negative effects for REE user companies *relative* to Chinese supplier firms after each MOFCOM announcement and on average for all MOFCOM announcements. Finally, we show changes in wealth transfer effects before and after the initiation of the WTO trial.

In line with our predictions, we find that sudden extreme price increases are accompanied by price increases for Chinese REE supplier companies and by price declines for U.S. REE user companies, and vice versa. In contrast, we find statistically significant share price reactions for the U.S. relative to Chinese companies for only some MOFCOM announcements. Furthermore, the reactions documented show neither a consistent picture of a relative wealth transfer from U.S. REE users to Chinese REE supplier companies, nor a statistically significant joint effect over the entire observation period. However, if we divide our sample into pre- and post-WTO trial subsamples, we find that U.S. REE user companies on average realize higher returns than Chinese REE suppliers in response to MOFCOM announcements after the WTO trial. This suggests that either 1) REE market conditions became more favorable for REE users outside China, or 2) at the beginning of the WTO trial, the Chinese government changed its behaviour, presumably to avoid sanctions, which benefited REE users.

We also conduct a complementary analysis of a homogenous sample of twenty-two global firms supplying and/or refining REEs (which are included in the Market Vectors Global Rare Earth/Strategic Metals Index). We find that those firms are equally affected by price changes. Interestingly, however, we observe higher *CARs* for Chinese index firms than for non-Chinese firms prior to the WTO trial. We fail to find such evidence for the period after the WTO trial. These findings suggest that the Chinese government used their discretion over export quotas to the benefit of Chinese REE firms toward the beginning of the REE supply chain, and prior to the opening of the WTO trial (note again that we failed to find such evidence for the

aforementioned sample of U.S. REE user firms relative to Chinese REE supplying firms in the period prior to the WTO trial). The limited role of individual MOFCOM announcements could also be attributable to other important, but largely unobservable, event-specific features, such as illegal REE exports from China (TMR, 2010c).

To summarize, our findings lend only limited support to public concerns that China's REE policy will exploit other nations' wealth, and they suggest the value of considering a more integrated perspective. Furthermore, the export quotas may be simply a convenient public scapegoat, and are actually having only limited influence over what the markets commonly perceive to be the issue. This is especially true for the period after the WTO trial began. Consistent with the notion of Chinese policy adjustments after the beginning of the WTO trial, China recently announced to abolish export quotas (WSJ 2015).

Our results suggest that the volatility of REE prices is the more important issue. Focusing on how to reduce REE price volatility, rather than dwelling on the effects of China's monopoly, would ultimately be more fruitful. Therefore, our policy implication is to establish liquid trading on REE exchanges to give REE user companies the ability to hedge their exposures efficiently. From our perspective, the recent opening of the Baotou Rare Earth Products Exchange in May 2014, where contracts on some REEs are traded, is an important step in the right direction to increase the role of the free market and to counteract criticism over export quotas. Similarly, the addition of REEs to the Shanghai Futures Exchange, which is planned in the near future, may also provide the ability to hedge against price volatility (see Shen, 2014).

The remainder of this paper is structured as follows. Section 2 gives a detailed overview of the institutional backgrounds of REEs, from mining, through the refinery process, to industry usage. It also discusses recent developments in the rare earth market. In section 3, we describe our data bases and data gathering process, while section 4 discusses our event study

methodology. Our results and study limitations are presented in section 5. Section 6 concludes.

2. Institutional Background on Rare Earth Elements

REEs are made up of the fifteen elements of the lanthanide series (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium; atomic numbers 57-71). Scandium and yttrium (atomic numbers 21 and 39, respectively) are sometimes included in the family of rare earths, as these elements are closely related in the periodic system of the elements to the group of lanthanides (see, for example, Anstett, 1986; APS Panel on Public Affairs & The Materials Research Society, 2011; and Tse, 2011). Note that promethium has no natural occurrence, as it is a fission product of uranium.

These seventeen elements are classified as either light or heavy. In most classifications, light rare earths (cerium group) are the elements with atomic numbers 57-63; heavy rare earths (yttrium group) are the elements with atomic numbers 64-71 plus yttrium. However, classification is not completely uniform. Anstett (1986, p. 3) and Hedrick (2004b, p. 1), for example, classify europium as a light rare earth, while Bailey Grasso (2013, p. 8) classifies it as a heavy rare earth. Similarly, Hedrick (2004b, p. 1) and KNCV (2012) classify gadolinium as a heavy rare earth, while Baotou National Rare Earth Hi-Tech Industrial Development Zone (2013) classifies both europium and gadolinium as light rare earths. We follow Baotou National Rare Earth Hi-Tech Industrial Development Zone's definition, as it seems the most common.

The name rare earths is actually something of a misnomer. These elements are neither rare nor are they earths. The REE group gets its name from the fact that these elements are scattered, and concentration in ore is low. Most deposits contain less than 1% of REEs, and even the richest only contain up to 9%. Extraction and processing is therefore difficult and

costly (see Evans, 2011; KNCV, 2012; Looney, 2011, and online appendix 7). Furthermore, the majority (about 90%) of these elements are not extracted as primary products, but obtained largely as co- or byproducts (see Long et al., 2010, and APS Panel on Public Affairs & The Materials Research Society, 2011, for more details). Because demand for the principal products such as zinc is the driving force behind mining decisions, REE production is driven by demand for those products rather than demand for the rare earth elements themselves (Long et al., 2010). Hence, as demand for REEs increases, prices will also increase, because additional supply cannot be delivered in the short term.

2.1. Industry

The U.S. long dominated the rare earth industry. For example, from the mid-1960s to the mid-1980s, the Mountain Pass mine in California accounted for roughly 50% of global rare earth production (see Anstett, 1986, and USGS, 2002a). However, that began to change dramatically in the 1980s. Because of lower labour costs and environmental standards, China became the main producer, and now has a quasi-monopoly position with over 90% of global production (see Bailey Grasso, 2013, and Long et al., 2010).

The world's largest light rare earth deposit is in the Bayan Obo mining district, located in Baotou, Inner Mongolia, China (see Anstett, 1986; Jackson and Christiansen, 1993; and Baotou National Rare Earth Hi-Tech Industrial Development Zone, 2013). The Mountain Pass mine continues to be the site of the largest non-Chinese rare earth deposit (see GAO, 2010), although it primarily contains light rare earths. The U.S. had been totally self-reliant for rare earth oxides, but production greatly reduced after 1997, and it ceased completely in 2001 (see Figure 5). One of the largest REE mining corporations, Molycorp, was then forced to shut down its operations in Mountain Pass (USGS, 2002a, and Bourzac, 2011) because of (then) lower-priced Chinese imports, scandals over burst pipelines and water contamination, and

being denied permission to build a larger storage facility for tailings. Only recently did Molycorp restart some mining in Mountain Pass, producing about 800 metric tons in 2012.

— *Please insert Figure 5 about here* —

Today, only Chinese companies produce and sell rare earths in commercial quantities. Furthermore, China is the only country that produces heavy REEs (Massachusetts Institute of Technology's Energy Initiative, 2010). They currently control about 50% of global rare earth reserves, while the U.S. controls about 12% to 15% (see Figure 1). Figure 2 gives a visual representation of the development of Chinese mine production over time, and shows how heavily dependent the U.S. is on REE imports from China (up to 90% in recent years) (see Figure 4).

Production of rare earths at the Mountain Pass mine was recently restarted partly because of the rapid increase in demand and prices (see Bourzac, 2011). New mining operations also began recently in Mt. Weld and Nolans in Australia (see KNCV, 2012). Nevertheless, the supply from these new mining activities is unlikely to meet the demand, especially because there are no currently acceptable substitutes and demand is inelastic to price changes. Bourzac (2011) and KNCV (2012) believe shortages may occur for praseodymium, neodymium, terbium, and dysprosium. This may lead to shortages in such products as permanent magnets required for hybrid and electrical vehicles and wind energy turbines.

REE mining, separation, and smelting in China is exclusive to Chinese companies and those engaged in Sino-foreign joint ventures.³ However, as mentioned earlier, the Chinese government is thought to use those joint ventures as a way to induce foreign companies to produce downstream applications and research and development. This has given rise to some fears of technology tunneling (see Humphries, 2012, and Morrison and Tang, 2012). In

³ A Sino-Foreign Cooperative Joint Venture (CJV) is a joint venture between a Chinese and a foreign company within the territory of China. The Chinese company usually provides the labour, land use rights, and factory buildings; the foreign company is required to contribute the necessary technology and key equipment, as well as capital.

addition to mining and extraction, some processing and downstream value-adding activities such as production of alloys and metals have shifted to China.

Today, China is the main producer of both neodymium iron boron (NeFeB) and samarium cobalt (SmCo) permanent magnets, which are the strongest magnets available (see Bailey Grasso, 2013). China currently produces 89% of rare earth alloys, 75% of neodymium iron boron (NeFeB) permanent magnets, and 60% of samarium cobalt (SmCo) permanent magnets (see GAO, 2010). According to Humphries (2012), there were 130 NeFeB permanent magnet manufacturers in China in 2007, which generated output of 39,000 tons in 2006, with a total capacity estimated to be 80,000 tons. According to GAO (2010), there are some Japanese companies that produce rare earth metals as inputs for the production of alloys and magnets. However, they are also dependent on China, for the rare earth ore.

2.2. Applications

REEs possess special properties with regard to magnetism, electronics, and luminescence. They are vital for a variety of applications in high-tech and green technology fields (including defense and nuclear technology). They are also used widely in metallurgy, as catalysts, as glass additives, in glass polishing, and a variety of further applications (see, for example, Baotou National Rare Earth Hi-Tech Industrial Development Zone, 2013, as well as Table OA1 in the online appendix for a summary).

Anstett (1986) argues that one of the most important applications of REEs is as oil cracking catalysts, to convert crude oil into petroleum products. Adding REEs to petroleum cracking can increase capacity by 20%-30%, and gasoline production by about 5% (see also Baotou National Rare Earth Hi-Tech Industrial Development Zone, 2013). However, their use in permanent magnets is the primary worldwide application (see Hurst, 2010a, 2010b). Such magnets are used in a broad range of products, from hard disk and CD drives, to magnetic resonance imaging (MRI) equipment, to motors of electric and hybrid cars, and to wind

turbines, to convert torque into electricity. Hurst (2010a, 2010b) finds that the largest wind energy turbines require up to two tons of neodymium permanent magnets, and about 250 kg is neodymium. According to Humphries (2012), the demand for permanent magnets is forecasted to grow between 10% and 16% each year for the foreseeable future. The demand for rare earths in catalysts (automobile and petroleum cracking) is similarly expected to rise by 6% to 8% each year. Another increasingly important field of application is the use of neodymium in laser production.

Heavy rare earths such as yttrium are used in laser and phosphor production, and they are also facing increased demand from high-tech applications. Yttrium oxide and europium oxide are particularly important as phosphors in computer monitors and TV sets. Baotou National Rare Earth Hi-Tech Industrial Development Zone (2013) calculates that using phosphors in lamps can increase energy efficiency by up to 75%. Lanthanum, cerium, and gadolinium have similar uses in X-ray screens.

In addition to civil applications, rare earths also have many military defense applications, such as in aircrafts, submarines, and destroyers. Neodymium iron boron (NdFeB) and samarium cobalt (SmCo) permanent magnets are particularly important for military defense purposes, including the guidance and control of electric motors and actuators and in electric drive motors. Yttrium, europium, and terbium are used for amplification of energy and resolution in laser targeting, while neodymium, yttrium, lanthanum, lutetium, and europium amplify and enhance signal resolution (see, e.g., Hedrick, 2004b; Hurst, 2010a, and Bailey Grasso, 2013). However, according to Bailey Grasso (2013), only approximately 5% of total U.S. consumption is used for military applications.

Admittedly, not all REEs are of equal importance. Some, such as lutetium, currently have only limited demand (see Long et al., 2010). The consumption statistics for actively used REEs show that in 2008, about 129,000 metric tons of rare earth oxides were consumed (see Table OA2 of the online appendix). Of that, cerium oxide, at about 42,220 metric tons (one-

third of total REE consumption), is the most heavily consumed, followed by lanthanum oxide (38,655 metric tons, or 30.16%), neodymium oxide (22,868 metric tons, or 17.84%), and yttrium oxide (11,610 metric tons, 9.06%) (see also Goonan, 2011). These four elements together account for about 90% of global REE consumption.

Goonan (2011) calculates that the glass industry accounts for 44% of the total consumption of cerium oxide, with glass polishing using about 25% and glass additives capturing the remaining 19%. Automobile catalytic converters used 16%, metallurgy 14%, and battery alloys accounted for another 10%. With regard to lanthanum oxide, catalysts account for about 47% of total consumption, followed by battery alloys (16%) and the glass industry (21%). Neodymium oxide is most heavily used by neodymium magnets, which account for 80% of total consumption. For yttrium oxide, phosphors and ceramics are the two main sources of consumption, with 54% and 32%, respectively. Yttrium, lanthanum, and neodymium oxide are also used in advanced ceramics, and are needed in the electronics industry as well (see Baotou National Rare Earth Hi-Tech Industrial Development Zone, 2013).

2.3. MOFCOM Announcements

The Chinese Ministry of Commerce (MOFCOM) publishes two kinds of announcements on a regular basis: 1) export quota announcements, and 2) qualified export enterprise announcements. The former limits the absolute amount of REEs to be exported, and is generally published twice a year (i.e., one batch for the first half of the year and a second batch for the second half (see Table 1). The latter specifies the number of enterprises that will qualify as REE export companies. As Table 1 shows, the total quota from 2009 to 2010 dropped significantly. This reduction was attributable primarily to the quota announcement on July 8, 2010.

— Please insert Table 1 about here —

From 2010 to 2014, the total export quota per year remained mostly constant at around 30,000t. However, the distribution of each quota per year differed. In 2010, the first quota announcement represented approximately two-thirds of the ultimate total; in 2011, the first announcement only represented about half the total year quota. Interestingly, in 2012, the government switched from two announcements to three announcements per year, with one-third of the quota confirmed per announcement (but they also began announcing the total year's quota at the beginning of the year, and requiring some Chinese REE firms to undergo pollution control regulations).

The Chinese government also recently increased the level of granularity of its announcements, reporting on the amount of light and heavy rare earth export quotas separately with the first 2012 announcement.⁴ The total amount for light REEs was 18,595t for the first batch in 2012 (i.e., the original announcement of 9,095t from 27 December 2011 and the 9,500t that were added on May 17, 2012). This was more than double the amount for the second batch (8,537t). Similarly, the total was 2,641t for heavy REEs for the first batch in 2012, and it decreased to 1,233t for the second batch, i.e., a 53% reduction.

The number of qualified export enterprises was reduced from forty-seven in 2006 to thirty-nine in 2007. However, two companies were added later on April 24, 2007. Similarly, for 2008, twenty-three companies were given the qualified export enterprise status, with one more added subsequently, for a total of twenty-four. For 2009, twenty companies qualified, and three were added in August. For 2012, only eleven firms were granted the status of qualified export company; another twenty-one were subject to audit at the time of the announcement. For 2013, this number increased slightly, with twenty-five export enterprises and four that were subject to audit. For 2014, the Ministry of Commerce has granted twenty-eight companies the qualified export enterprise status. One general trend seems obvious: The

⁴ The quotas are as follows: December 27, 2011: 9,095t (L) and 1,451t (H); May 17, 2012: 9,500t (L) and 1,190t (H); August 22, 2012: 8,537t (L) and 1,233t (H); December 28, 2012: 13,561t (L) and 1,938t (H). L: light rare earth elements; H: heavy rare earth elements; t: tons.

Chinese government seems inclined to limit the number of companies that are allowed to export REEs.

In light of the recent events surrounding the REE export quotas and the sharp price increases, the U.S., Japan, and the EU jointly brought a dispute resolution case against China to the World Trade Organization (WTO) on March 13, 2012 (see European Commission, 2012). In June 2012, the Chinese government responded by stating that it will set export quotas in such a way as to satisfy “the normal demand of the international market” (Information Office of the State Council of The People’s Republic of China, 2012). Because they also increased the number of quota announcements that year in May (the higher frequency likely reduced uncertainty), this can be interpreted as a reaction towards the WTO case.

The dispute resolution panel ultimately ruled that the export quota announcements are at odds with GATT (the General Agreement on Tariffs and Trade). It was issued to all WTO members on March 26, 2014. Both the U.S. and China filed notices of appeal with the WTO’s appellate body, which came to the same conclusion. The resolution was adopted by the dispute settlement body on August 29, 2014. Figure OA1 in the online appendix and TMR (2014) provide a more detailed overview of the WTO dispute resolution case.

3. Data

Our sample period is January 1, 2008-August 31, 2014, and includes all thirteen available MOFCOM announcements in Table 1. We use data from four databases:

- REE prices for oxides and metals come from the Asian Metal database. All prices are in USD/kg for FOB (export) and China (domestic). If USD prices are not available, we use the official CNY/USD exchange rate available from the Federal Reserve System for conversion (see <http://www.federalreserve.gov/datadownload>).

Note from Figure 3 that light REEs are generally lower in price than heavy REEs. The exceptions are cerium, with the lowest price at 1.30 USD/kg and the highest price at 150.55 USD/kg, and europium, with the lowest price at 230.00 USD/kg and the highest at 5,590.00 USD/kg. And, of course, we observe that Chinese prices are generally considerably lower than FOB prices. The price difference is larger for light REEs: For cerium, the maximum difference is about 1,301%, and for lanthanum it is 1,875%; for yttrium, the maximum is 930%. We note that FOB and China prices tend to move in the same direction, as all correlations for both oxides and metals of single REEs are positive (see Table OA3, panel A in the online appendix).

For oxides, praseodymium exhibits the highest correlation between FOB and China prices; for metals, terbium has the highest (0.6570 and 0.5868, respectively). For both oxides and metals, the lowest correlation is found for cerium (0.2816 and 0.2585, respectively). With regard to weekly returns, all oxide prices of the REEs exhibit positive skewness (FOB prices for yttrium being the exception), and are also leptokurtic (see Table OA4 in the online appendix). Similarly, weekly returns of all metal prices show positive skewness and leptokurtosis. Correlations between the individual elements are all positive, which suggests that REE prices tend to move in the same direction (see Tables OA5 and OA6 in the online appendix).

For our event study, with regard to extreme price observations (see Table 2), we use oxide prices because they “are traded much more extensively than high-purity compounds and metals” (see Jackson and Christiansen, 1993, p. 42).

- Chinese companies are listed on either the Shanghai or the Shenzhen stock exchange. We identify Chinese companies in the REE business from the MOFCOM announcements, which list all firms given export quotas. From this list, we identify fourteen publicly listed firms, which are either in the mining or processing business of rare earths, or have some other REE-related business model. Stock price data and firm

characteristics (size, growth, ROE (return on equity), and leverage) come from the China Stock Market Trading Database (CSMAR). We exclude initial listing day returns due to extreme returns. If a company is not traded, we set the return to zero.

- U.S. companies in the rare earth business are identified as follows. We perform a text search within all 10-K and 8-K filings for the past four years using the SEC's EDGAR Full-Text Search.⁵ Specifically, we search for filings containing the term “rare earth”, or the name of at least one of the seventeen rare earth materials as detailed in Table OA7 in the online appendix. Via this search strategy, we initially identify 253 unique firms, of which we are able to match 106 with the Center for Research in Security Prices (CRSP) database for price data and Compustat for firm characteristics (size, growth, ROE (return on equity), and leverage).⁶
- Finally, we use a homogenous group of Chinese and global (ex-China) REE supplier and refiner firms from the Market Vectors Global Rare Earth/Strategic Metals Index in order to complement our primary analyses that focus on a comparison of Chinese REE supplier versus U.S. REE user firms. This index includes the twenty-two largest and most liquid firms in the global rare earths and strategic metals segment. To be included, firms must generate at least 50% of their revenues from rare earths and strategic metals, or from mining projects with the potential to generate at least 50% of their revenues from rare earths/strategic metals when developed. The index includes refiners, recyclers, and producers of rare earth strategic metals and minerals. For this sample (REE index firms), we obtain price and accounting data from Thomson Reuters Datastream, respectively.

⁵ Accessible via https://searchwww.sec.gov/EDGARFSCClient/jsp/EDGAR_MainAccess.jsp.

⁶ We decompose the sample of U.S. companies by industry by using Fama-French industry codings based on forty-eight industries obtained from the companies' SIC codes. The decomposition reveals that only 2.58% of the sample companies are classified as either “Precious Metals” or “Non-Metallic and Industrial Metal Mining.” This implies that our sample of U.S. companies consists of firms located further to the end of the supply chain, i.e., REE users. As a robustness check, we excluded these firms, and obtained virtually identical results. The tables are available from the authors upon request. Industry classifications are from Kenneth French's website: http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/Data_Library/det_48_ind_port.html.

4. Methodology

We aim to analyze value effects for listed companies involved in the rare earth business in China and the U.S. in response to changes in China's rare earth policy. We apply a market model in an event study context using pre-event data over a 100-day estimation period, beginning from $t_0 - 120$ until $t_0 - 20$, where t_0 is the MOFCOM announcement date (see Brown and Warner, 1980, 1985, and MacKinlay, 1997, for details).

More precisely, we calculate *abnormal returns* (ARs) as the residuals of regressing the individual companies' stock returns on the market portfolio returns: $AR_{it} = R_{it} - \hat{\alpha}_i - \hat{\beta}_i R_{mt}$, where R_{it} and R_{mt} are the returns at time t of company i and a market index m , respectively, and $\hat{\alpha}_i$ and $\hat{\beta}_i$ are estimates of the constant and the slope from the regression. We use the CRSP equally weighted index for U.S. REE user companies and an equally weighted index of all shares traded on Shanghai and Shenzhen for Chinese suppliers, respectively, for the respective market index. We choose the MSCI World index for our REE index firm sample because its index constituents come from twelve different countries.

We then aggregate ARs over the event period to calculate *cumulative abnormal returns* ($CARs$). In addition to calculating $CARs$ in response to the MOFCOM announcements, we calculate them in response to extreme REE price movements. We define extreme price movements as price reactions on a single day that exceed ± 1.5 standard deviations, based on a fifteen-week rolling window. However, if we find consecutive dates of extreme price events on the same side of the distribution for either $+1.5$ or -1.5 standard deviations, we only use the first date of occurrence. If the two extreme events are on different sides of the distribution (e.g., an extreme event on $+1.5$ standard deviations, and the consecutive event on -1.5 standard deviations, or vice versa), we consider both events.

Finally, we require a minimum period of four weeks until a new extreme price event on the same side of the distribution is recorded.⁷ We flag extreme price events exceeding ± 1.5 standard deviations in order to balance between identifying extreme price movements that cause stock price changes and finding a “reasonable” number of observations. If the required standard deviation band is too wide, the number of observations could be too low; if the required standard deviation band is too narrow, other information could confound that of the REE price movements, and the information content itself might not be sufficient to cause stock price changes. We rerun our analysis for ± 1 - and ± 2 -standard deviation bands as a robustness check (see Table OA8 in the online appendix).

In a second step, we estimate OLS regression models that explain the *CARs* for different event windows around the MOFCOM announcements. Here, we control for company-specific characteristics (size, growth, return on equity (ROE), and leverage as summarized by the *Controls* in Equation (1)), and industry fixed effects (the dummy for first digit of the SIC code).

$$CAR[-t_{\tau_1}; +t_{\tau_2}] = \alpha + \beta_1 \cdot US + \sum_j \gamma_j \cdot Controls_{j,t} + \phi_k + \varepsilon_t, \quad (1)$$

where $CAR[-t_{\tau_1}; +t_{\tau_2}]$ is the cumulative abnormal return for the event window beginning τ_1 days before the MOFCOM announcement and ending τ_2 days after the announcement, α is the constant, US is a dummy variable equal to 1 if a company is listed in the U.S., $Controls_{j,t}$ are company-specific characteristics for company j for the respective year t , and ϕ_k are the industry fixed effects (for clarity, we omit firm-level notations).

⁷ We examined whether the detected extreme price events coincide with the thirteen MOFCOM announcements in Table 1, and find that none of the ± 1.5 - or ± 2 -standard deviation extreme price events took place at the same time. For ± 1 -standard deviation extreme price events, we found there were two MOFCOM announcements two and three days before we recorded the extreme price event. To determine whether those events alter our results, we reran the event studies for the extreme price events defined by ± 1 -standard deviation excluding those two events. Our results were virtually the same.

We first estimate this regression separately for each of the thirteen MOFCOM announcements. We thus cover all publically available MOFCOM announcements beginning with their introduction on July 7, 2008, and going through July 8, 2014. Next, we examine the relative performance of U.S. companies that rely on REEs relative to Chinese supplier firms across all thirteen events (*US* dummy variable). In this setting, we are not interpreting the absolute effects on U.S. or Chinese companies. So expectations about, e.g., quotas are “canceled out,” because market participants form expectations about reactions for U.S. and Chinese companies. We are only able to measure relative performance, which we interpret as a wealth transfer.

Finally, we split our sample period into pre- and post-WTO dispute resolution case (March 13, 2012) subsamples. In other words, we test for differences across Chinese suppliers and U.S. REE users across the first eight MOFCOM announcements (pre-WTO) and across the remaining five announcements at a time when the WTO case was ongoing (post-WTO). As previously indicated, we also replicate the analyses for the REE index firms by testing for differences across Chinese and non-Chinese REE suppliers and refiners across all events as well as pre- and post-WTO. In these regressions, we include a *China* dummy variable instead of a *US* dummy variable in Equation (1).

5. Results

5.1. Empirical Analysis

This section presents our empirical evidence to answer our research question of whether the Chinese REE policy results in wealth transfers from the U.S. to China. We provide evidence along four dimensions: 1) we show the average performance of U.S. REE user companies as well as global and Chinese REE supplier companies around extreme REE price movements (see Table 2), 2) we use multivariate regressions to test separately for the average

performance of U.S. REE user companies relative to Chinese REE supplier firms in response to individual MOFCOM announcements (see Table 3), 3) we test jointly for the average performance of U.S. REE user companies relative to Chinese REE supplier firms in response to MOFCOM announcements, both pre- and post-WTO (see Table 4), and 4) we use similar methodology as in (1) and (3), but comparing global and Chinese REE suppliers and refiners (see Table 5).

The first analysis investigates the relationship between extreme REE price movements and subsequent returns for REE users and suppliers. Our rationale here is to determine whether severe REE price movements impact the margins and profits of REE material users and suppliers, which should be translated into the stock prices. The underlying assumption is that stock price reactions should depend on the relative place in the supply chain and on extreme REE decreases or increases.

The REE supply chain generally follows the structure of mining, refining, alloying, and manufacturing. We hypothesize that extreme REE price increases will be favourable for REE suppliers that are at the front of the supply chain (mining, refining), and unfavourable for REE users (manufacturing) at the end of the supply chain, and vice versa. We define an extreme REE price movement if the price of the usage-weighted REE index (based on FOB prices) on a given date deviates more than ± 1.5 standard deviations (up or down) based on a fifteen-week rolling window. To underline the robustness of our results, see Table OA8 in the online appendix, which gives the results for ± 1 - and ± 2 -standard deviation bands as a trigger for extreme price movements.

As the univariate analysis in Table 2 shows, Chinese and global REE supplier companies react positively to events with extreme price increases (see Table 2, panels A and E), while U.S. REE user firms react negatively (see Table 2, panel C). In contrast, we observe the opposite if REEs show an extreme price decrease.

This analysis reveals that companies involved in the REE industry not only react to extreme price changes, but, as hypothesized, they react in accordance with their position in the REE supply chain. Because these results are in line with economic intuition, this analysis also supports the notion that the search strategy we used to identify U.S. REE user firms succeeded in locating firms with exposure to REE price movements and that are users of REEs (that is, located toward the end of the supply chain).

Section 2 of Table OA8 in the online appendix gives the results for the ± 1 -standard deviation bands as a trigger for extreme price movements. The results are similar to those presented above, but the average returns are lower. We interpret this monotonic decrease for less extreme price movements as further support for our argument, because lower REE price movements should be associated with lesser stock price reactions. However, the statistical significance is reduced compared to the ± 1.5 -standard deviation analysis. One reason for this may be that observations of ± 1 standard deviation around the mean are obviously less “extreme” than observations of ± 1.5 standard deviations. They may not be strong enough to trigger subsequent stock price reactions, because other information about, e.g., industry perspectives can easily confound the REE price movement information.

On a related note, an examination of the more extreme REE price movements (± 2 standard deviations) reveals other interesting insights. The dynamics for the share price reactions of the global REE suppliers and refiners change when we focus on more extreme price increases (see section 1 in Table OA8 in the online appendix). For lower price changes (± 1.5 standard deviations), we note similar share price reactions for both the global and Chinese REE suppliers and refiners, but more extreme price changes are only beneficial for Chinese and negative for global REE suppliers and refiners. We attribute this to the fact that those companies are closer to the beginning of the REE supply chain. Therefore, sudden REE price increases (decreases) on average are assumed to positively (negatively) affect their profits and be associated with stock price increases (decreases). However, during the 2011-late 2012 time

period, REE prices rose dramatically (see Figure 3), and companies outside China also had only limited access to REEs (see Morrison and Tang, 2012). Given that six out of nine ± 2 -standard deviation events are within this time period, the average stock price declines could be reflecting the unequal access to REEs for global suppliers and refiners.⁸

— Please insert Table 2 about here —

Next, we explore whether U.S. REE user and Chinese REE supplier firms' stock prices react differently to the thirteen MOFCOM export quota announcements. We study the cross-sectional determinants of *CARs* across five different event windows. We include a dummy variable for U.S. REE firms, and expect a negative coefficient for U.S. firms if allegations that export quota announcements are detrimental to U.S. firm value are correct.

Our first set of these analyses are presented in Table 3. For each of the thirteen MOFCOM announcement events, we estimate five regressions for the five different event windows. In line with Equation (1), we control for other firm-characteristics and for industry fixed effects.⁹ For the sake of brevity, however, we only report the estimated coefficient on our primary variable of interest and the related test statistic (i.e., the US dummy). Each entry in the table reports the result of one regression. The control variables are mostly insignificant, and are hence of little informational value.¹⁰

The results we obtain in Table 3 are largely mixed. For events 2, 9, and 10, we find larger market reactions for U.S. REE firms than for Chinese REE firms. For events 11 and 13, we find lower market reactions for U.S. REE firms. For event 5, the results change based on the event window. The results for the other events are largely insignificant, or only marginally significant in one of the event windows.

We interpret our results to mean that the announced export quotas in general do not trigger a wealth transfer from U.S. REE users to Chinese REE supplier firms. However, it seems that

⁸ Note that we found no events of extreme price reductions on the lower bound.

⁹ In total there are sixty-five regressions, which is for thirteen MOFCOM events times five event windows.

¹⁰ Detailed tables including the coefficients of all control variables are available from the authors upon request.

investors are able to put the export quotas into perspective, and weight any further information jointly distributed with the MOFCOM announcements. For example, Table 1 illustrates that the export quota decreased significantly at the fourth event, but the market reaction was insignificant (see Table 1). That is, a naïve expectation formed on the year-on-year change in quota is too simplistic to explain the market reaction. Other event-specific factors, such as the actual exports that also include exports via illegal channels, are likely to jointly determine the market reaction to the quota announcement.

Because we focus on the relative differences between U.S. and Chinese REE firms, these factors may not bias the coefficient. However, if these factors affect both groups differently, then we may fail to detect statistical differences. That is, we compare firms at different stages in the supply chain and these may be affected differently by quota announcements, e.g., U.S. REE users or their suppliers along the supply chain may still have inventory. To summarize, it is difficult to systematically interpret single event announcement returns.

— Please insert Table 3 about here —

In Table 4, we test for differences in market reactions across all events. We perform these analyses partly because event-specific factors in an analysis may cancel each other out across multiple events. Moreover, our initial event regressions may suffer from power issues, given that our sample of fourteen Chinese REE supplier firms is relatively small. The setup of Table 4 mirrors that of Table 3. We estimate a regression including firm controls and industry fixed effects, but we only present the primary variable of interest, the dummy variable for U.S. REE user firms.¹¹

Panel A of Table 4 generally confirms the results in Table 3. Market reactions of U.S. REE users do not differ significantly or consistently across the event windows from those of Chinese REE suppliers. When we split our sample period into pre- and post-WTO subsamples

¹¹ An enlarged table including the coefficients of the control variables is available in the online appendix (see Table OA9).

(e.g., prior to event 8 (panel B) and from event 8 onward (panel C)), we find insignificant differences in the stock price reactions between U.S. and Chinese REE firms pre-WTO, and statistically significant positive market reactions for U.S. REE user firms post-WTO. This suggests that the WTO trial triggered a response by the Chinese government that was also reflected in the MOFCOM announcements and was beneficial for U.S. REE user firms. However, because pre-WTO the market reaction to these announcements was not statistically different for U.S. user and Chinese REE supplier firms, it is hard to interpret this result overall.

— Please insert Table 4 about here —

In Table 5, we replicate the analyses from Table 4 by using a homogenous sample of the largest and most liquid listed refiners and producers in the global rare earths and strategic metals segment included in the Market Vectors Global Rare Earth/Strategic Metals Index. These firms are thus located toward the beginning of the supply chain. We benchmark the *CARs* of four Chinese firms against all non-Chinese firms across all events. We also split the sample period into pre- and post-WTO subsamples again. We estimate regressions including firm-level controls and industry fixed effects, but only report the coefficient of interest, the *China* dummy variable (that is, we estimate the relative difference between Chinese and global REE refiner and producer firm *CARs* as a response to the MOFCOM announcements).¹²

Results across all events reveal a significantly positive difference in *CARs* for Chinese REE index firms. This suggests that the Chinese government is using its discretion over export quotas to the benefit of Chinese REE firms. When we consider our subsamples, we find that the positive difference is largely attributable to the pre-WTO events. Taken together, these results lend some support to the allegations cited earlier, but they only hold for the pre-

¹² Note again that the table containing the coefficients of the control variables can be accessed in the online appendix. Please see Table OA9.

WTO period. In other words, just as for the U.S. REE users, the results indicate that the WTO trial may have triggered an adjustment by the Chinese government when reporting MOFCOM announcements. Because some event-specific information is largely unobservable, or only available with large measurement errors (e.g., illegal exports), it is difficult to specify through which channels the Chinese government adjusted their policy, given that the quotas announced were largely comparable year-on-year for the post-WTO period.

— *Please insert Tables 5 about here* —

5.2. Limitations and Avenues for Further Research

We note that our results are subject to several limitations. For example, we do not model potential determinants of the market reactions along two key dimensions. First, our analysis does not include macro-data, which refers to any actual oversupply before the announcement and the actual shipment of rare earths during the period between two announcements, or the market's export quota expectations. To the extent that these variables affect U.S. REE users and Chinese REE suppliers differently, this could bias our results. Second, our analysis is unable to control for firm-level data, such as the level of inventories for U.S. firms, to proxy for the level of stockpiling or exposure to REEs as proxied for by, e.g., a disclosure score related to REEs. However, the series of significant results over multiple events and event windows increases our comfort that our results are not driven by non-random firm- or group-specific confounding effects that could have been concentrated around the event dates. Furthermore, MOFCOM has begun to announce individual quota levels for light and heavy rare earth materials, as well as for Chinese and joint venture firms, and our tests do not discriminate between these two types of firms or elements. These limitations provide valuable paths for future research to contribute to the ongoing deliberations about China's rare earth policy.

Moreover, China's industrial policy with regard to monopolistic competition and the market power of the rare earth conglomerates may also provide further research opportunities. There is some fear that the centralization of the REE industry and the creation of large government-run corporations could ultimately hinder innovation (Pitelis, 2013).

Another important topic for future research is the WTO dispute resolution case. The principal-agent framework proposed by Pitelis (2013), where supra-national institutions as the principal should ensure that individual nations (the agents) pursue policies that spur global value creation and do not hinder innovation, seems quite meaningful. The question then becomes how to align the interests of the Chinese government with those of the global markets. The aspect of illegal mining should also undergo a thorough investigation. Lu (2009) has identified measures taken to prevent lawless actions as one of the most pressing challenges facing China. In this light, it would be worthwhile to explore in-depth the measures China has taken to prevent illegal mining, and how they have impacted output volume, prices, and the sustainability of rare earth resources. Besides the economic impact of ongoing regulations, the environmental impact of policies against illegal mining should also be considered.

6. Conclusion

This paper focused first on the REE market and its institutional background to provide a concrete overview. We used descriptive analyses to discuss the market's price developments, outputs, etc., over time. Second, we used export quota announcements to analyze whether China misuses its quasi-monopoly position in the REE market to exploit profits for its own industry at the expense of other countries' rare earth end-use industries. In an event study context, we then calculated *CARs* in response to the quota announcements for listed Chinese REE suppliers and U.S. REE user companies for different event windows. We subsequently used these as the dependent variables for multivariate regressions. If China is indeed using its

market power for a wealth transfer effect, we expect this to be revealed in the regressions. Surprisingly, our results do not fully support the view of a wealth transfer, because neither the reactions to individual MOFCOM announcements nor the joint effect for all announcements are consistently negative for U.S. companies. However, we find some evidence after the beginning of the WTO trial that U.S. REE user firms on average had more positive reactions than Chinese supplier firms. Moreover, for a sample of the largest and most liquid REE supplier and refiner firms included in the Market Vectors Global Rare Earth/Strategic Metals Index, we find that Chinese firms reacted more favorably to MOFCOM announcements prior to the WTO trial.

Collectively, these results suggest that China may have used its market power to the benefit of Chinese REE supplier firms prior to the WTO trial, and then adjusted its strategy as reflected by MOFCOM announcements after the trial began, which benefited U.S. REE user and global, non-Chinese REE supplier firms. Our results suggest that the trial triggered a change in the Chinese REE policy consistent with China's recent announcement to abolish export quotas (WSJ 2015). However, these conclusions must be interpreted with caution, and considered against the limitation of certain unobservable, event-specific factors.

Therefore, we must also examine the reactions of U.S. REE user and Chinese REE supplier companies to extreme REE price movements. In an event study context, we find that Chinese and global REE supplier companies react positively (negatively) to events with extreme price increases (decreases), while U.S. REE user firms react negatively (positively). This reveals that companies not only react to extreme price changes, but also, as hypothesized, in accordance with their position along the REE supply chain.

Pitelis (2013) discusses value-generating strategies for sustainable economic development. In light of this framework, we find only limited support for value-capturing strategies by Chinese companies or the Chinese government. This has implications for companies active in the rare earth industry and international trade policy alike: Although companies that need

REEs as inputs must note MOFCOM's semiannual announcements of rare earth export quotas, the information content of those announcements does not appear to trigger economically significant or systematic wealth transfer effects between China and the U.S., probably because the export quotas do not increase the price volatility of REEs.

However, it is important to note that industry research (TMR, 2010c) typically highlights a difference between actual shipments from China to the rest of the world and the official reported demand, which is attributable to, e.g., smuggling. Furthermore, companies that depend on REEs may have inventories that can shield them in the short term from decreasing quota announcements (TMR, 2010a).

Finally, anecdotal evidence suggests that the market forms an expectation about the quota announcement and of long-term REE prices. There seems to be an industry consensus that, due to increasing costs of energy and labour in China as well as increased environmental regulation, prices will be higher than the low prices experienced prior to 2007/2008 (TMR, 2010b). All of these factors will combine to determine whether the market perceives MOFCOM's quota announcements as beneficial or detrimental to shareholder value for Chinese and U.S. firms. Companies that are highly dependent on REEs may want to consider establishing strategic REE stocks in order to avoid quota and price uncertainties. Long-term contracts could also serve to shield companies from uncertainties. The potential provision to establish security exchanges for, e.g., REE derivatives in order to hedge against extreme price volatility is one step in this direction (Shen, 2014).

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Figure 1: Rare Earth Reserves

This figure gives an overview of rare earth distributions based on information from the U.S. Geological Survey (USGS) from 1995-2013. The remaining reserves are divided between Australia, Brazil, India, Malaysia, Sri Lanka, and the rest of the world. More precisely, we use the REE sections from the Mineral Yearbooks and the Commodity Summaries for rare earths. See Hedrick, 1995-2010; Cordier and Hedrick, 2010; Cordier, 2011; Gambogi and Cordier, 2012, and USGS, 2013.

Figure 2: World Mine Production of Rare Earths

The left figure shows global (total) and Chinese mine production; the right figure shows Chinese mine production as a percentage of global mine production. Data come from the U.S. Geological Survey (USGS). More precisely, we use the REE sections from the Mineral Yearbooks and the Commodity Summaries for rare earths. See Hedrick, 1994a-2010; Cordier and Hedrick, 2010; Cordier, 2011; Gambogi and Cordier, 2012, and USGS, 2013.

Figure 3: Prices of Rare Earth Elements

This figure shows the price developments for all REEs over time. For REEs with FOB and China prices, both developments are shown, as well as the percentage difference between them. For gadolinium, holmium, lutetium, scandium, and ytterbium oxide, only China prices are shown. For samarium oxide, we only show the FOB price development because the purity is 99%min, while for the China prices it is 99.9%min and therefore lacks comparability. All data come from the Asian Metals database. The different lengths of the time series are due to data availability: For FOB prices of lanthanum, cerium, praseodymium, neodymium, samarium, europium, terbium, and dysprosium, the time series begins in January 2004. For FOB prices of yttrium and erbium, the time series begins in August 2010. For China prices of yttrium, lanthanum, cerium, praseodymium, neodymium, europium, terbium, and dysprosium, the time series begins in January 2005. For China prices of erbium, the time series begins in January 2009. For China prices of gadolinium, the time series begins in July 2010. For China prices of scandium, holmium, and ytterbium, the time series begins in November 2010. All time series end in November 2013.

Figure 4: U.S. Rare Earth Imports

The left figure shows total U.S. REE imports in metric tons per year and the amount imported from China; the right figure shows the percentage of U.S. REE imports from China. Data come from the U.S. Geological Survey (USGS). More precisely, we use the REE sections from the Mineral Yearbooks and the Commodity Summaries for rare earths. See Hedrick, 1994a-2010; Cordier and Hedrick, 2010; Cordier, 2011; Gambogi and Cordier, 2012, and USGS, 2013.

Figure 5: U.S. Rare Earth Production

This figure shows total U.S. production of REEs in metric tons per year. Data come from the U.S. Geological Survey (USGS). More precisely, we use the REE sections from the Mineral Yearbooks and the Commodity Summaries for rare earths. See Hedrick, 1994a-2010; Cordier and Hedrick, 2010; Cordier, 2011; Gambogi and Cordier, 2012, and USGS, 2013. A summary can be found in the sections on REEs from the historical statistics for mineral and material commodities in the United States. See Kelly and Matos, 2013.

Table 1: MOFCOM Export Quota Announcements and the Number of Qualified Export Companies

This table shows the MOFCOM export quota announcements (panel A), and the announcements of qualified export companies (panel B). Information on the MOFCOM announcements of export quotas and qualified export companies is obtained from the webpage of the Ministry of Commerce of the People's Republic of China (MOFCOM) —see <http://www.mofcom.gov.cn/article/b/e/>. JV: Joint venture; H1: First half of the year; H2: second half of the year.

Panel A: MOFCOM Events						
No.	Date	Quota (t)	Thereof JV (t)	Period	Year	Total year (t)
1	July 7 th , 2008	11,376		H2	2008	
	End of 2008	21,728	6,685	H1	2009	
2	June 30 th , 2009	28,417	10,160	H2	2009	50,145
3	December 31 st , 2009	22,282	5,978	H1	2010	
4	July 8 th , 2010	7,976	1,768	H2	2010	30,258
5	December 28 th , 2010	14,508	3,746	H1	2011	
6	July 14 th , 2011	15,738	3,517	H2	2011	30,246
7	December 27 th , 2011	10,546	5,160	H1a	2012	
8	May 17 th , 2012	10,680		H1b	2012	
9	August 22 th , 2012	9,770	3,430	H2	2012	30,996
10	December 28 th , 2012	15,499	4,363	H1	2013	
11	July 1 st , 2013	15,500	4,337	H2	2013	30,999
12	December 13 th , 2013	15,110	4,345	H1	2014	
13	July 8 th , 2014	15,500	3,465	H2	2014	30,610
Panel B: Qualified Export Enterprises						
No.	Date	Number of Export Companies				
1	January 4 th , 2006	47				
2	December 26 th , 2006	39				
3	April 24 th , 2007	2				
4	January 3 rd , 2008	23				
5	May 7 th , 2008	1				
6	December 12 th , 2008	20				
7	August 12 th , 2009	3				
8	December 29 th , 2009	22				
9	December 14 th , 2010	31 (1 subject to audit)				
10	December 14 th , 2011	11 (21 subject to audit)				
11	December 17 th , 2012	25 (4 subject to audit)				
12	December, 13 th , 2013	28				

Table 2: CAARs for Chinese REE Supplier, U.S. REE User, and Global REE Supplier and Refiner Companies After Extreme Price Events

This table reports equally weighted cumulative average abnormal returns (*CAAR*) in response to extreme price events (t_0) for various event windows, using a market model with an estimation period of $t_0 - 120$ until $t_0 - 20$ for listed Chinese REE supplier (panels A and B) and U.S. REE user companies (panels C and D), and global REE supplier and refiner companies (excluding China) (panels E and F). We define a date as an extreme price event if the price of the usage weighted REE index (based on FOB prices) on that date deviates more than ± 1.5 standard deviations from the mean, based on a fifteen-week rolling window for the estimation of the standard deviation. If consecutive dates of extreme events on the same side of the distribution are recorded for either $+1.5 \cdot \sigma$ (positive deviation) or $-1.5 \cdot \sigma$ (negative deviation), only the first date of occurrence will be used. If the two extreme events are on different sides of the distribution (extreme event on $+1.5 \cdot \sigma$ (positive deviation) and the consecutive event on $-1.5 \cdot \sigma$ (negative deviation) or vice versa), both events will be considered. Finally, we require a minimum period of four weeks until a new extreme price event on the same side of the distribution is recorded. Panels A, C, and E show the results for positive deviations; panels B, D, and F show results for negative deviations. The observation period is from January 1, 2008 until August 31, 2014. Test statistics are the Boehmer, Musumeci, and Poulsen (1991) *z*-score, the *t*-values, and the *J*-value (Johnson, 1978). Nobs are the number of observed extreme price events times the number of companies. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

(continued)

Table 2: CAARs for Chinese REE Supplier, U.S. REE User, and Global REE Supplier and Refiner Companies—continued

		CAAR		Boehmer Test	t-Test	Johnson Test	
Event window	Mean	Median	t-value	z-score	J-value	Nobs	
Panel A: Chinese REEs Supplier Companies							
[0;+1]	0.43%	0.50%	0.813	1.083	1.082	140	
[0;+3]	2.11%	1.19%	4.207***	4.113***	4.173***	140	
[0;+5]	3.45%	2.58%	6.812***	6.235***	6.327***	140	
[0;+10]	4.22%	4.22%	6.049***	5.701***	5.756***	140	
[-5;+1]	2.30%	2.09%	2.698***	2.779***	2.778***	140	
[-5;+3]	3.98%	2.73%	4.324***	4.163***	4.213***	140	
[-5;+10]	6.09%	4.83%	5.772***	5.425***	5.495***	140	
Panel B: Chinese REEs Supplier Companies							
[0;+1]	-0.58%	-0.74%	-1.206	-1.489	-1.483	154	
[0;+3]	0.42%	-0.83%	0.610	0.765	0.768	154	
[0;+5]	-2.91%	-2.34%	-3.719***	-3.828***	-3.834***	154	
[0;+10]	-0.30%	-0.01%	-0.055	-0.267	-0.267	154	
[-5;+1]	0.51%	-3.44%	-0.054	0.641	0.643	154	
[-5;+3]	1.50%	-3.01%	0.850	1.532	1.542	154	
[-5;+10]	0.79%	-2.71%	0.271	0.544	0.545	154	
Panel C: U.S. REEs User Companies							
[0;+1]	-0.20%	0.03%	-0.942	-1.213	-1.212	1,243	
[0;+3]	-2.48%	-1.23%	-9.738***	-9.108***	-9.116***	1,243	
[0;+5]	-2.85%	-1.71%	-9.525***	-8.870***	-8.869***	1,241	
[0;+10]	-0.69%	-0.93%	-2.521**	-1.858*	-1.858*	1,240	
[-5;+1]	-0.86%	-0.42%	-2.682***	-2.558**	-2.558**	1,243	
[-5;+3]	-3.14%	-1.53%	-7.995***	-7.263***	-7.272***	1,243	
[-5;+10]	-1.35%	-1.63%	-3.488***	-2.844***	-2.842***	1,240	
Panel D: U.S. REEs User Companies							
[0;+1]	0.44%	0.23%	2.504**	2.463**	2.469**	1,228	
[0;+3]	0.57%	0.17%	3.635***	2.334**	2.337**	1,228	
[0;+5]	0.46%	0.65%	2.659***	1.536	1.537	1,227	
[0;+10]	0.25%	-0.15%	0.068	0.553	0.553	1,226	
[-5;+1]	0.14%	-0.30%	1.059	0.377	0.377	1,228	
[-5;+3]	0.26%	0.27%	2.140**	0.677	0.678	1,228	
[-5;+10]	-0.06%	-0.49%	-0.083	-0.099	-0.099	1,226	
Panel E: Global REEs Supplier and Refiner Companies (excluding China)							
[0;+1]	1.22%	-0.05%	1.396	1.412	1.449	166	
[0;+3]	2.06%	0.27%	2.337**	2.011**	2.059**	166	
[0;+5]	2.84%	1.11%	3.029***	2.644***	2.703***	166	
[0;+10]	4.23%	2.15%	3.689***	3.298***	3.356***	166	
[-5;+1]	0.57%	-0.27%	0.949	0.592	0.597	166	
[-5;+3]	1.41%	-0.07%	1.876*	1.227	1.238	166	
[-5;+10]	3.59%	2.18%	3.289***	2.616***	2.634***	166	
Panel F: Global REEs Supplier and Refiner Companies (excluding China)							
[0;+1]	-0.65%	-0.04%	-1.512	-1.622	-1.621	194	
[0;+3]	-2.07%	-1.08%	-3.159***	-3.286***	-3.289***	194	
[0;+5]	-3.76%	-1.49%	-4.595***	-4.591***	-4.622***	194	
[0;+10]	-2.25%	-1.68%	-2.793***	-2.696***	-2.698***	194	
[-5;+1]	-1.88%	-1.28%	-2.732***	-2.617***	-2.614***	194	
[-5;+3]	-3.30%	-1.82%	-3.642***	-3.566***	-3.565***	194	
[-5;+10]	-3.47%	-2.41%	-3.514***	-3.277***	-3.277***	194	

Table 3: Relative Performance of Chinese REE Supplier and U.S. REE User Companies in Response to MOFCOM Announcements

This table reports results of multivariate OLS regressions for five event windows around the individual MOFCOM events (events 1 to 13 each in a separate regression and for each event window) using standard errors clustered on firm level (see Equation (1)). The dependent variables are the equally weighted *CARs* for Chinese REE suppliers and U.S. REE users in response to the individual MOFCOM announcements from Table 1 (t_0) for various event windows applying a market model. The estimation period ranges from $t_0 - 120$ until $t_0 - 20$. Explanatory variables include a *US* dummy variable (1 if the *CAR* stems from a U.S. company), and further control variables, which are not reported. Those control variables include industry fixed effects and firm controls (size ($\ln(\text{total assets})$), growth (percentage change in sales), return on equity (ROE) (income before extraordinary items divided by total equity), and leverage (debt divided by total equity). Growth, ROE, and leverage are winsorized at the 1% and 99% levels. Robust standard errors are in parentheses. *F* denotes the average *F*-statistic of the 13 regressions for the respective event window. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

		Dependent Variable: <i>CAR</i>				
		Event Window				
Event		[0;3]	[0;5]	[0;10]	[-5;3]	[-5;10]
Event 1	US	0.007 (0.021)	-0.010 (0.024)	0.007 (0.033)	-0.091*** (0.022)	-0.090*** (0.031)
Event 2	US	0.049*** (0.017)	0.049** (0.019)	0.062** (0.025)	0.059** (0.028)	0.071** (0.032)
Event 3	US	-0.019 (0.015)	0.003 (0.018)	-0.029 (0.030)	-0.005 (0.015)	-0.016 (0.030)
Event 4	US	0.007 (0.008)	0.029** (0.013)	0.001 (0.020)	0.029* (0.015)	0.022 (0.022)
Event 5	US	-0.031*** (0.010)	-0.008 (0.012)	0.065*** (0.017)	0.011 (0.019)	0.106*** (0.025)
Event 6	US	0.003 (0.011)	0.006 (0.013)	-0.007 (0.016)	-0.031 (0.026)	-0.042 (0.027)
Event 7	US	-0.030* (0.017)	0.015 (0.025)	-0.043 (0.033)	0.010 (0.024)	-0.003 (0.041)
Event 8	US	-0.032*** (0.009)	-0.044*** (0.012)	-0.055*** (0.016)	-0.072*** (0.018)	-0.094*** (0.023)
Event 9	US	0.042*** (0.011)	0.095*** (0.019)	0.083*** (0.025)	0.061*** (0.012)	0.102*** (0.025)
Event 10	US	0.071*** (0.008)	0.061*** (0.012)	0.043*** (0.016)	0.096*** (0.013)	0.068*** (0.018)
Event 11	US	-0.025*** (0.004)	-0.014*** (0.006)	-0.031*** (0.011)	0.017 (0.014)	0.011 (0.016)
Event 12	US	0.011 (0.007)	0.016* (0.008)	0.037*** (0.012)	-0.012 (0.010)	0.014 (0.014)
Event 13	US	-0.035*** (0.012)	-0.065*** (0.018)	-0.053*** (0.020)	-0.018 (0.012)	-0.036* (0.019)
<i>F</i>		1.93*	3.08***	2.05*	1.72	1.98*

Table 4: Relative Performance of Chinese REE Supplier Compared to U.S. REE User Companies Before and After the Beginning of the WTO Trial

This table reports multivariate OLS regressions for five event windows using standard errors clustered on firm level (see Equation (1)). The dependent variables are the equally weighted *CARs* for Chinese REE suppliers and U.S. REE users in response to MOFCOM announcements from Table 1 (t_0) for various event windows applying a market model. The estimation period ranges from $t_0 - 120$ until $t_0 - 20$. Explanatory variables include a *US* dummy variable (1 if the *CAR* stems from a U.S. company), and further control variables, which are not reported. Those control variables include industry fixed effects and firm controls (size ($\ln(\text{total assets})$), growth (percentage change in sales), return on equity (ROE) (income before extraordinary items divided by total equity), and leverage (debt divided by total equity). Growth, ROE, and leverage are winsorized at the 1% and 99% levels. Panel A reports results for all MOFCOM events; panel B reports results for *CARs* around events pre-WTO; panel C reports results for *CARs* around events post-WTO. Nobs are the number of observations. Robust standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Event Window				
	[0;3]	[0;5]	[0;10]	[-5;3]	[-5;10]
Panel A: All Events					
US	0.002 (0.003)	0.010*** (0.004)	0.007 (0.005)	0.006 (0.005)	0.012* (0.007)
Nobs	1,281	1,281	1,281	1,281	1,281
<i>F</i>	0.82	2.72***	5.53***	3.10***	3.18***
Panel B: Pre WTO Dispute Resolution Case					
US	-0.002 (0.004)	0.011* (0.006)	0.009 (0.008)	-0.001 (0.008)	0.010 (0.010)
Nobs	630	630	630	630	630
<i>F</i>	2.35**	12.41***	3.54***	2.91***	6.11***
Panel C: Post WTO Dispute Resolution Case					
US	0.005** (0.003)	0.008* (0.004)	0.005 (0.006)	0.013** (0.005)	0.012* (0.007)
Nobs	651	651	651	651	651
<i>F</i>	2.75***	1.73*	16.98***	4.10***	25.61***

Table 5: Relative Performance of Chinese REE Supplier and Refiner Companies Compared to other Global Supplier and Refiner Companies Pre- and Post-WTO Trial

This table reports multivariate OLS regressions for five event windows using standard errors clustered on firm level (see Equation (1)). The dependent variables are the equally weighted *CARs* for Chinese and non-Chinese companies that are constituents of the Market Vectors Global Rare Earth/Strategic Metals Index in response to MOFCOM announcements from Table 1 (t_0) for various event windows applying a market model. The estimation period ranges from $t_0 - 120$ until $t_0 - 20$. Explanatory variables include a *China* dummy variable (1 if the *CAR* stems from a Chinese company), and further control variables, which are not reported. Those control variables include industry fixed effects and firm controls (size ($\ln(\text{total assets})$), growth (percentage change in sales), return on equity (ROE) (income before extraordinary items divided by total equity), and leverage (debt divided by total equity). Growth, ROE, and leverage are winsorized at the 1% and 99% levels. Panel A reports results for all MOFCOM events; panel B reports results for *CARs* around events pre-WTO; panel C reports results for *CARs* around events post-WTO. Nobs are the number of observations. Robust standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

	Event Window				
	[0;3]	[0;5]	[0;10]	[-5;3]	[-5;10]
Panel A: All Events					
China	0.030*** (0.008)	0.030*** (0.010)	0.031** (0.012)	0.027* (0.015)	0.028 (0.017)
Nobs	242	242	242	242	242
F	2.96***	1.64	0.78	1.91*	0.65
Panel B: Pre WTO Dispute Resolution Case					
China	0.036*** (0.008)	0.043*** (0.014)	0.047*** (0.014)	0.044* (0.021)	0.055* (0.029)
Nobs	127	127	127	127	127
F	1.56	1.75	1.32	1.53	1.19
Panel C: Post WTO Dispute Resolution Case					
China	0.021 (0.013)	0.017 (0.013)	0.016 (0.020)	0.005 (0.018)	0.000 (0.023)
Nobs	115	115	115	115	115
F	2.14**	1.17	0.16	2.47**	0.38

Wealth Effects of Rare Earth Prices and China's Rare Earth Elements Policy

Maximilian Müller, Denis Schweizer and Volker Seiler

Online Appendix

Figure OA1: Overview of WTO Dispute Resolution Case

This figure shows an overview of the main events of the dispute resolution case launched by the U.S., the EU, and Japan against China concerning China's export policies with regard to REEs. The figure is based on TMR (2014) and WTO (2014a, b, c, d, e, f).

Table OA1: Applications of Rare Earth Elements

This table gives an overview of the fields of application for each REE. Classification is analogous to Jackson and Christiansen, 1993, and Hurst, 2010a, 2010b.

Element	Symbol	Field of Application
Cerium	Ce	<ul style="list-style-type: none"> - Environmental protection and pollution control - Automobile catalytic converters - Jet engines - Petroleum refining catalyst - Diesel fuel additive - Metallurgy - Glass polishing - Carbon-arc lighting - Lighter flints
Dysprosium	Dy	<ul style="list-style-type: none"> - High performance motors in next-generation vehicles - Wind power generation - Energy-saving consumer electronics
Erbium	Er	<ul style="list-style-type: none"> - Amplifier in long-range fiber optic data transmission - Lasers for medical and dental use - Coloring glass (e.g., sunglasses and decorative crystal glasses) - Metallurgy
Europium	Eu	<ul style="list-style-type: none"> - Red phosphors used in TVs and computer screens - Fluorescent lighting - Biochemical agents for tissue research - Control rods in nuclear reactors
Gadolinium	Gd	<ul style="list-style-type: none"> - Magneto-optic recording technology - Magnetic resonance imaging (MRI) - Garnets for microwave applications - Phosphors for TVs - Metallurgy
Holmium	Ho	<ul style="list-style-type: none"> - No commercial usage
Lanthanum	La	<ul style="list-style-type: none"> - Petroleum refining catalysts - Fuel cells and batteries - Optical lenses (camera lenses) - Night vision instruments - TVs - Lighter flints - Ceramic glazes - Optical fibers - X-ray films - Lasers - Hydrogen sponge alloys
Lutetium	Lu	<ul style="list-style-type: none"> - Catalysts in cracking, alkylation, hydrogenation, and polymerization - Positron emission tomography (PET) Radar systems - Neutron absorber in nuclear reactors - Filtering glasses - Carbon-arc lighting

(continued)

Table OA1: Applications of Rare Earth Elements—*continued*

Neodymium	Nd	<ul style="list-style-type: none">- Permanent magnets for- Consumer electronics (cell phones, CD players, computers, sound systems)- Motors (wind energy turbines, electric and hybrid cars)- Lasers- Ceramic capacitors- Coloring pigment (ceramic tiles, glass)- Lighter flints
Praseodymium	Pr	<ul style="list-style-type: none">- Aircraft engines- Coloring pigment (ceramic tiles, glass, enamel)- Permanent magnets- Capacitors- Fiber optics- Photographic filters- Airport signal lenses- Welders glasses- Lighter flints
Promethium	Pm	<ul style="list-style-type: none">- Thickness gages
Samarium	Sm	<ul style="list-style-type: none">- Permanent magnets (especially for aerospace and defense applications)- Radar systems- Neutron absorber in nuclear reactors- Filtering glasses- Carbon-arc lighting
Scandium	Sc	<ul style="list-style-type: none">- High performance materials for aerospace- Lasers- Lighting- Consumer electronics
Terbium	Tb	<ul style="list-style-type: none">- Energy efficient lighting- Magneto-optic data recording- Crystal stabilizer in fuel cells
Thulium	Tm	<ul style="list-style-type: none">- X-rays
Ytterbium	Yb	<ul style="list-style-type: none">- Stress gauges to monitor ground deformations (e.g. caused by earthquakes or explosions)- Metallurgy
Yttrium	Y	<ul style="list-style-type: none">- Improved fuel efficiency and reduced pollution of car engines- Microwave communication devices- Frequency meters, magnetic field measurement, tunable transistors, Gunn oscillators- Stabilizer (jet engines, rocket nose cones)- Laser crystals (military communication)- TVs

Table OA2: Usage of Rare Earth Elements by Industry

This table shows the various end usage of rare earth oxides in 2008. Panel A shows metric tons (t) of rare earth oxides and panel B the percentage of rare earth oxides as to end use. Table is based on Goonan (2011). Ce: cerium; La: lanthanum; Nd: neodymium; Y: yttrium; Pr: praseodymium; Dy: dysprosium; Gd: gadolinium; Sm: samarium; Tb: Terbium; Eu: Europium. Light rare earths: Ce, La, Nd, Pr, Sm; heavy rare earths: Y, Dy, Gd, Tb, Eu.

End Use	Rare Earth Oxide										
	Ce	La	Nd	Y	Pr	Dy	Gd	Sm	Tb	Eu	Other
<i>Panel A: Metric Tons (t) of Rare Earth Oxides</i>											
Automobile catalytic converters	6,840	380	228	-	152	-	-	-	-	-	-
Ceramics	840	1,190	840	3,710	420	-	-	-	-	-	-
Fluid catalytic cracking	1,980	17,800	-	-	-	-	-	-	-	-	-
Glass additives	7,920	2,880	360	240	120	-	-	-	-	-	480
Metallurgy, except batteries	5,980	2,990	1,900	-	633	-	-	-	-	-	-
Neodymium magnets	-	-	18,200	-	6,140	1,310	525	-	53	-	-
Battery alloys	4,040	6,050	1,210	-	399	-	-	399	-	-	-
Phosphors	990	765	-	6,230	-	-	132	-	414	441	-
Glass polishing	10,700	5,170	-	-	574	-	-	-	-	-	-
Other	2,930	1,430	130	1,430	300	-	75	150	-	-	75
Total	42,220	38,655	22,868	11,610	8,738	1,310	762	549	467	441	555
<i>Panel B: Percentage (%) of Rare Earth Oxides as to End Use</i>											
Automobile catalytic converters	16.20	0.98	1.00	-	1.74	-	-	-	-	-	-
Ceramics	1.99	3.08	3.67	31.96	4.81	-	-	-	-	-	-
Fluid catalytic cracking	4.69	46.05	-	-	-	-	-	-	-	-	-
Glass additives	18.76	7.45	1.57	2.07	1.37	-	-	-	-	-	86.49
Metallurgy, except batteries	14.16	7.74	8.31	-	7.24	-	-	-	-	-	-
Neodymium magnets	-	-	79.59	-	70.27	100.00	68.90	-	11.35	-	-
Battery alloys	9.57	15.65	5.29	-	4.57	-	-	72.68	-	-	-
Phosphors	2.34	1.98	-	53.66	-	-	21.26	-	88.65	100.00	-
Glass polishing	25.34	13.37	-	-	6.57	-	-	-	-	-	-
Other	6.94	3.70	0.57	12.32	3.43	-	9.84	27.32	-	-	13.51
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table OA3: Correlation Between FOB and China Returns and Oxide and Metal Returns

This table shows in panel A the correlations of FOB and China returns for rare earth oxides and metals and in panel B the correlations of oxide and metal returns for FOB and China prices. All calculations are based on the period January 1, 2004-November 8, 2013. Depending on data availability, the period might differ for single elements: For FOB prices of lanthanum, cerium, praseodymium, neodymium, samarium, europium, terbium, and dysprosium oxide, the time series begins in January 2004. For FOB prices of yttrium and erbium oxide, the time series begins in August 2010. For China prices of yttrium, lanthanum, cerium, praseodymium, neodymium, europium, terbium, and dysprosium oxide, the time series begins in January 2005. For China prices of erbium oxide, the time series begins in January 2009. For China prices of gadolinium oxide, the time series begins in July 2010. For China prices of scandium, holmium, and ytterbium oxide, the time series begins in November 2010. For metals, the time series for FOB prices begins in January 2004; the time series for China prices begins in January 2005. Calculations are based on prices from the Asian Metals database; all calculations based on USD/kg. Ce: cerium; Dy: dysprosium; Er: erbium; Eu: europium; Gd: gadolinium; Ho: holmium; La: lanthanum; Lu: lutetium; Nd: neodymium; Pr: praseodymium; Sc: scandium; Sm: samarium; Tb: terbium; Y: yttrium; Yb: ytterbium; EWI: equally weighted REEs index; UWI: usage weighted REEs index; na: not available.

Element	Panel A		Panel B	
	Oxides	Metals	FOB	China
Ce	0.2816	0.2585	0.7133	0.4428
Dy	0.5091	0.5618	0.8580	0.8766
Er	0.4307	na	na	na
Eu	0.6431	na	0.8108	na
Gd	na	na	na	na
Ho	na	na	na	na
La	0.2974	0.2825	0.7710	0.7104
Lu	na	na	na	na
Nd	0.6525	0.5777	0.7205	0.8414
Pr	0.6570	na	0.6641	na
Sc	na	na	na	na
Sm	na	0.2763	0.5837	na
Tb	0.6259	0.5868	0.7514	0.7931
Y	0.2911	na	na	na
Yb	na	na	na	na
EWI	0.5092	na	na	na
UWI	0.4743	na	na	na

Table OA4: Descriptive Statistics of Rare Earth Element Returns

This table gives the mean, standard deviation, skewness, kurtosis, minimum, and maximum for the weekly log-return distributions of REE prices for the January 1, 2004-November 8, 2013 period. Depending on data availability, the period might differ for single elements: For FOB prices of lanthanum, cerium, praseodymium, neodymium, samarium, europium, terbium, and dysprosium oxide, the time series begins in January 2004. For FOB prices of yttrium and erbium oxide, the time series begins in August 2010. For China prices of yttrium, lanthanum, cerium, praseodymium, neodymium, europium, terbium, and dysprosium oxide, the time series begins in January 2005. For China prices of erbium oxide, the time series begins in January 2009. For China prices of gadolinium oxide, the time series begins in July 2010. For China prices of scandium, holmium, and ytterbium oxide, the time series begins in November 2010. For metals, the time series for FOB prices begins in January 2004; the time series for China prices begins in January 2005. Returns are based on end-of-week price and the prior week's end-of-week price. Price data comes from the Asian Metals database; all calculations based on USD/kg. Panels A through C are based on oxide prices: Panel A shows results for light REEs, panel B for heavy REEs, and panel C for REE indices. We calculate two indices: The equally weighted REE-Index is calculated as the equally weighted average return for all REEs for which both, FOB and China prices are available. The usage weighted REE-Index is calculated as the end usage weighted (weights are calculated as in Table OA2) average return for the four most important REEs as to end use (cerium, lanthanum, neodymium, yttrium). These four elements account for about 90% of all rare earth usage. Panels D through F are based on metal prices: Panel D shows results for light REEs, panel E shows results for heavy REEs, and panel F shows results for the REE-Index. As metal prices for yttrium are not available, only the statistics for the equally weighted index are displayed. Na: not available.

Element		Mean (%)	Std. Dev. (%)	Skewness	Kurtosis	Min (%)	Max (%)
<i>Panel A: Light Rare Earth Elements - Oxides</i>							
Lanthanum	FOB	0.2515	5.7444	5.9102	77.8952	-19.7064	79.5464
	China	0.2137	3.9662	4.1957	28.5485	-12.2383	32.7266
Cerium	FOB	0.3115	6.3973	6.6527	88.0544	-23.5120	91.2557
	China	0.2616	3.8067	1.5935	15.6668	-25.6443	26.0562
Praseodymium	FOB	0.6548	3.7769	2.1700	13.0546	-13.6305	29.5065
	China	0.5617	3.7596	1.7323	13.5250	-14.1468	27.2856
Neodymium	FOB	0.5540	4.1687	1.9726	10.1446	-15.1231	23.8615
	China	0.4565	3.7635	0.8356	5.3077	-14.1468	18.4028
Samarium	FOB	0.2985	10.9429	17.1269	342.3149	-31.8454	220.3836
	China	na	na	na	na	na	na
Europium	FOB	0.3039	4.3391	7.2963	99.7978	-18.1346	63.8614
	China	0.2520	4.1121	3.8387	35.0352	-17.5421	43.1380
Gadolinium	FOB	na	na	na	na	na	na
	China	0.7449	9.4572	3.0601	22.1692	-36.7055	67.0247
<i>Panel B: Heavy Rare Earth Elements - Oxides</i>							
Scandium	FOB	na	na	na	na	na	na
	China	0.4353	2.9112	3.4175	18.1762	-8.0209	18.3524
Yttrium	FOB	-0.3051	5.7630	-0.0807	4.1003	-25.1314	22.2062
	China	0.1396	4.3882	4.6492	45.7122	-11.7720	50.5095
Terbium	FOB	0.3317	4.4361	3.7653	33.6598	-21.5111	46.3715
	China	0.2147	4.0460	1.6315	20.8621	-25.5210	36.0936
Dysprosium	FOB	0.6766	4.0428	3.9260	30.7422	-12.3444	41.6073
	China	0.5156	4.4012	1.7856	10.2268	-16.1076	27.5130
Holmium	FOB	na	na	na	na	na	na
	China	0.5147	7.8257	2.7620	13.1872	-18.3639	48.7420
Erbium	FOB	0.0215	4.5290	1.5670	12.7182	-17.9971	27.7802
	China	0.6344	3.9500	0.5309	7.0057	-19.6629	19.2885
Ytterbium	FOB	na	na	na	na	na	na
	China	0.5310	6.5384	2.3007	29.2788	-34.0509	43.3336
Lutetium	FOB	na	na	na	na	na	na
	China	1.0730	5.6295	3.0347	17.5483	-20.9647	34.1780

(continued)

Table OA4: Descriptive Statistics of Rare Earth Element Returns—*continued*

<i>Panel C: Rare Earth Elements Indices - Oxides</i>							
Equally	FOB	0.4698	4.0860	3.7192	34.0738	-11.8418	45.1356
Weighted REE- Index	China	0.3396	3.1530	1.8625	10.1350	-9.7304	23.1428
Usage	FOB	0.4685	4.4003	4.8573	50.1515	-12.7768	53.9809
Weighted REE- Index	China	0.3519	3.0723	1.7515	9.1939	-9.4590	20.2184
<i>Panel D: Light Rare Earth Elements - Metals</i>							
Lanthanum	FOB	0.2545	4.9352	5.0627	53.7797	-17.0626	59.4987
	China	0.1957	3.2912	4.9622	42.5513	-10.5732	34.9696
Cerium	FOB	0.2717	5.3298	5.0870	44.7662	-14.5712	59.6816
	China	0.2376	4.0283	2.4723	29.7189	-24.8137	34.9660
Praseodymium	FOB	0.6386	3.7138	1.6029	7.9390	-17.8248	19.7266
	China	na	na	na	na	na	na
Neodymium	FOB	0.5670	3.9561	1.6826	9.5014	-15.8433	29.2089
	China	0.4658	3.5356	0.7323	5.3405	-14.2398	18.6302
Samarium	FOB	0.3020	4.3914	5.5455	50.8280	-16.0343	44.8123
	China	0.1338	4.2496	8.2243	120.5947	-17.0150	63.5943
Europium	FOB	0.1779	3.9870	7.6402	106.2760	-24.0676	58.0763
	China	na	na	na	na	na	na
<i>Panel E: Heavy Rare Earth Elements - Metals</i>							
Terbium	FOB	0.2781	4.3486	2.9726	25.4015	-24.5122	38.2674
	China	0.1470	4.1067	3.4687	26.3914	-12.7818	35.3877
Dysprosium	FOB	0.6283	3.7562	2.8723	22.3853	-17.6931	33.8195
	China	0.5167	4.2594	1.9191	14.9918	-15.8877	31.2081
<i>Panel F: Rare Earth Elements Index - Metals</i>							
Equally	FOB	0.3683	3.6419	2.7682	19.4627	-15.6328	31.7379
Weighted REE- Index	China	0.2426	3.9054	2.5029	17.8574	-17.3531	31.9673

Table OA5: Correlation Matrix of Rare Earth Elements Returns – Oxides

This table provides an overview of the return correlations of rare earths oxides for the period January 1, 2004-November 8, 2013. Depending on data availability, the period might differ for single elements: For FOB prices of lanthanum, cerium, praseodymium, neodymium, samarium, europium, terbium, and dysprosium, the time series begins in January 2004. For FOB prices of yttrium and erbium, the time series begins in August 2010. For China prices of yttrium, lanthanum, cerium, praseodymium, neodymium, europium, terbium, and dysprosium, the time series begins in January 2005. For China prices of erbium, the time series begins in January 2009. For China prices of gadolinium, the time series begins in July 2010. For China prices of scandium, holmium, and ytterbium, the time series begins in November 2010. The upper diagonal matrix shows the correlations for returns based on FOB prices, while the lower diagonal matrix presents the correlations for returns based on China prices. Calculations are based on prices from the Asian Metals database; all calculations based on USD/kg. Ce: cerium; Dy: dysprosium; Er: erbium; Eu: europium; Gd: gadolinium; Ho: holmium; La: lanthanum; Lu: lutetium; Nd: neodymium; Pr: praseodymium; Sc: scandium; Sm: samarium; Tb: terbium; Y: yttrium; Yb: ytterbium; EWI: equally weighted REE index; UWI: usage weighted REE index; na: not available.

	Ce	Dy	Er	Eu	Gd	Ho	La	Lu	Nd	Pr	Sc	Sm	Tb	Y	Yb	EWI	UWI
Ce		0.1784	0.4522	0.1802	na	na	0.8631	na	0.4659	0.4636	na	0.3239	0.2447	0.5167	na	0.7763	0.8507
Dy	0.2363		0.5632	0.6530	na	na	0.2166	na	0.5438	0.4226	na	0.0923	0.7177	0.3115	na	0.4057	0.3564
Er	0.4434	0.604		0.4249	na	na	0.4551	na	0.6348	0.6248	na	0.5041	0.4823	0.3783	na	0.6209	0.6117
Eu	0.3172	0.6839	0.4834		na	na	0.1778	na	0.4407	0.3262	na	0.1225	0.7032	0.3199	na	0.3471	0.3086
Gd	0.4488	0.4962	0.4028	0.4962		na	na	na	na	na	na	na	na	na	na	na	na
Ho	0.4079	0.6826	0.5388	0.7973	0.4968		na	na	na	na	na	na	na	na	na	na	na
La	0.6215	0.2204	0.3160	0.3187	0.2207	0.2875		na	0.4867	0.4912	na	0.2568	0.2531	0.5222	na	0.7935	0.8644
Lu	0.2351	0.3194	0.3165	0.2607	0.1780	0.3827	0.1230		na	na	na	na	na	na	na	na	na
Nd	0.3966	0.6003	0.5937	0.5847	0.6087	0.7536	0.3112	0.3307		0.8159	na	0.3256	0.5066	0.3735	na	0.8524	0.7897
Pr	0.3802	0.5047	0.4815	0.5062	0.6534	0.6047	0.2739	0.1974	0.8077		na	0.3319	0.4194	0.3963	na	0.764	0.7173
Sc	0.6634	0.2968	0.4216	0.3291	0.3962	0.3363	0.5351	0.2070	0.4406	0.3348		na	na	na	na	na	na
Sm	na	na	na	na	na	na	na	na	na	na	na		0.1111	0.4200	na	0.3692	0.3549
Tb	0.2656	0.7233	0.5708	0.7620	0.4987	0.7001	0.2450	0.2658	0.5671	0.5278	0.3727	na		0.3749	na	0.4347	0.3928
Y	0.4071	0.5069	0.5194	0.5597	0.5792	0.5454	0.3133	0.1883	0.4779	0.5281	0.4915	na	0.5569		na	0.7612	0.6467
Yb	0.3571	0.1409	0.2406	0.0782	0.1770	0.2020	0.2332	0.5066	0.2123	0.2481	0.4053	na	0.1844	0.2472		na	na
EWI	0.5550	0.6311	0.6356	0.6592	0.6397	0.7369	0.4812	0.3107	0.9388	0.8067	0.5528	na	0.6251	0.7070	0.2684		0.9748
UWI	0.6206	0.5970	0.6219	0.6306	0.6170	0.7130	0.5607	0.3112	0.9333	0.7921	0.5764	na	0.5889	0.6323	0.2830	0.9891	

Table OA6: Correlation Matrix of Rare Earth Elements Returns – Metals

This table provides an overview of the return correlations of rare earth metals for the period January 1, 2004-November 8, 2013. Depending on data availability, the period might differ for single elements: The time series for FOB prices begins in January 2004; the time series for China prices begins in January 2005. The upper diagonal matrix shows the correlations for returns based on FOB prices, while the lower diagonal matrix presents the correlations for returns based on China prices. Calculations are based on prices from the Asian Metals database; all calculations based on USD/kg. Ce: cerium; Dy: dysprosium; Er: europium; La: lanthanum; Nd: neodymium; Pr: praseodymium; Sm: samarium; Tb: terbium; na: not available.

	Ce	Dy	Eu	La	Nd	Pr	Sm	Tb
Ce		0.2724	0.2611	0.7784	0.3701	0.3368	0.5267	0.1913
Dy	0.2472		0.6399	0.2636	0.5150	0.3522	0.2762	0.6142
Eu	na	na		0.2559	0.3270	0.2006	0.2491	0.6746
La	0.5779	0.2345	Na		0.3799	0.3401	0.5559	0.2032
Nd	0.3152	0.5408	Na	0.3571		0.7098	0.4907	0.4107
Pr	na	na	Na	na	na		0.4231	0.3056
Sm	0.1458	0.2790	Na	0.1821	0.3005	na		0.2470
Tb	0.2073	0.6818	Na	0.3024	0.5501	na	0.3284	

Online Appendix 7: Geology and Mineralogy of Rare Earths Elements

More than 100 minerals are known to contain REEs; however, the concentration in most of the minerals is too low to allow for mining as an ore. The most important minerals for mining rare earths are Monazite, Bastnäsite, and Xenotime (see Anstett, 1986, and Jackson and Christiansen, 1993). Monazite can contain up to 70% of rare earth oxides, and bastnäsite up to 75%, while xenotime contains about 67% rare earth oxides. The light REEs usually make up 80%-99% of a deposit, as they are more abundant and concentrated (see Humphries, 2012). Bastnäsite and monazite contain mainly light rare earths; however, the amount of heavy rare earths is two to three times higher in monazite compared to bastnäsite (see Hurst, 2010b).

Xenotime is the major source for yttrium and heavy rare earths, while monazite typically contains radioactive thorium (see, for example, Jackson and Christiansen, 1993, p. 10; Hedrick, 2004b, p. 2; Hurst, 2010b, p. 4, and Baotou National Rare Earth Hi-Tech Industrial Development Zone, 2013). Table OA7 gives an overview of the concentrations of the single REEs in different ores.

— Please insert Table OA7 about here —

Mining and processing rare earths is complex and expensive, and is generally conducted in five steps, according to GAO (2010), Hurst (2010b), and Humphries (2012):

1. Mining: Extraction of the ore from the mineral deposits.
2. Separating: Creation of rare earth concentrate and separation of individual rare earth oxides.
3. Reduction: Refining the rare earth oxides into metals.
4. Alloying: Processing the rare earth metals into rare earth alloys.
5. Manufacturing: Production of devices and components from the rare earth alloys, e.g., permanent magnets.

The single elements are usually not found separately, but are rather mixed together and often contain radioactive elements such as thorium and uranium. Because REEs tend to have a

high reactivity and are chemically similar, purification and separation of the individual elements is difficult (see Jackson and Christiansen, 1993). Extracting the elements from ore involves flotation of the crushed ore and dissolving in acid. Accordingly, the production of rare earths produces toxic and hazardous waste (Bourzac, 2011).

Table OA7: Main Minerals for Rare Earth Mining

This table gives an overview of minerals that can be used for rare earth production. Z: Atomic number; Symbol: symbol in the periodic table; Element: rare earth element name; L/H: light or heavy rare earth element; REO: Rare earth oxide; Na: Not applicable. Data is obtained from Anstett (1986, p. 3) and Jackson and Christiansen (1993, p. 9). First percentage rate in columns of the minerals monazite, bastnäsité, and xenotime are lowest estimates; the second are highest estimates as of Anstett (1986) and Jackson and Christiansen (1993). Curly brackets mean that complete separations between different REEs cannot be made precisely, e.g., xenotime consists of 10.6% lanthanum, cerium, praseodymium, and neodymium, with unknown composition among these elements.

Z	Symbol	Element	L/H	Rare Earth Oxide Contained in Major Source Minerals (% of Total REO)		
				Monazite	Bastnäsité	Xenotime
21	Sc	Scandium	H	Na	Na	Na
39	Y	Yttrium	H	1.950 – 2.000	0.100	60.000
57	La	Lanthanum	L	23.000	32.000	10.600
58	Ce	Cerium	L	46.000 – 46.500	49.500 - 50.000	
59	Pr	Praseodymium	L	5.000 – 5.100	4.000 – 4.200	
60	Nd	Neodymium	L	18.400 – 19.000	13.000	
61	Pm	Promethium	L	Na	Na	Na
62	Sm	Samarium	L	2.300 – 3.000	0.500 – 0.800	1.200
63	Eu	Europium	L/H	0.070 – 0.100	0.100 – 0.110	0.010
64	Gd	Gadolinium	L/H	1.700	0.150	3.600
65	Tb	Terbium	H	0.160	0 – 0.120	1.000
66	Dy	Dysprosium	H	0.500 – 0.520		7.500
67	Ho	Holmium	H	0.090		2.000
68	Er	Erbium	H	0.130		6.200
69	Tm	Thulium	H	0.010 – 0.013	0 – 0.020	1.270
70	Yb	Ytterbium	H	0.060 – 0.061		5.000 – 6.000
71	Lu	Lutetium	H	0.006		0.630

Table OA8: CAARs for Chinese REE Supplier, U.S. REE User, and Global REE Supplier and Refiner Companies After Extreme Price Events (± 2 and ± 1 standard deviations)

This table reports equally weighted cumulative average abnormal returns (CAAR) in response to extreme price events (t_0) for various event windows, applying a market model with an estimation period $t_0 - 120$ until $t_0 - 20$ for listed Chinese REE supplier (panels A and B) and U.S. REE user (panels C and D) companies, and global REE supplier and refiner companies (excluding China) (panels E and F). In Section 1 (section 2), we define a date as an extreme price event if the price of the usage weighted REE index (based on FOB prices) on that date deviates more than ± 2 standard deviations (± 1 standard deviations) from the mean, based on a fifteen-week rolling window for the estimation of the standard deviation. The following description is based on ± 1 standard deviation, but the systematic is analogous to ± 2 standard deviations. If consecutive dates of extreme events on the same side of the distribution are recorded for either $+1 \cdot \sigma$ (positive deviation) or $-1 \cdot \sigma$ (negative deviation), only the first date of occurrence will be used. If the two extreme events are on different sides of the distribution (extreme event on $+1 \cdot \sigma$ (positive deviation) and the consecutive event on $-1 \cdot \sigma$ (negative deviation) or vice versa), both events will be considered. Finally, we require a minimum period of four weeks until a new extreme price event on the same side of the distribution is recorded. Panels A, C, and E show the results for positive deviations; panels B, D, and F show results for negative deviations. The observation period is from January 1, 2008 until August 31, 2014. Test statistics are the Boehmer, Musumeci, and Poulsen (1991) z -score, the t -values, and the J -value (Johnson, 1978). Nobs are the number of observed extreme price events times the number of companies. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Section 1	CAAR		Boehmer Test	t-Test	Johnson Test	
Event window	Mean	Median	t-value	z-score	J-value	Nobs (#)
Panel A: Chinese Rare Earth Companies						
[0;+1]	0.76%	0.35%	2.612***	2.386**	2.412**	126
[0;+3]	1.46%	0.88%	3.547***	3.141***	3.183***	126
[0;+5]	1.48%	1.41%	3.700***	3.188***	3.211***	126
[0;+10]	2.90%	1.80%	4.052***	3.676***	3.724***	126
[-5;+1]	1.63%	1.57%	3.107***	2.915***	2.920***	126
[-5;+3]	2.33%	1.80%	3.884***	3.508***	3.536***	126
[-5;+10]	3.77%	3.01%	4.295***	3.923***	3.957***	126
Panel C: U.S. Rare Earth Companies						
[0;+1]	-0.24%	0.02%	-0.934	-1.170	-1.168	939
[0;+3]	-1.83%	-0.46%	-5.273***	-5.435***	-5.439***	939
[0;+5]	-0.35%	0.00%	-0.814	-1.069	-1.069	938
[0;+10]	-0.75%	-1.04%	-2.354**	-1.695*	-1.694*	938
[-5;+1]	-2.27%	-1.12%	-5.740***	-5.270***	-5.269***	939
[-5;+3]	-3.86%	-1.80%	-7.722***	-7.194***	-7.206***	939
[-5;+10]	-2.77%	-2.31%	-5.573***	-4.751***	-4.748***	938
Panel E: Largest and Most Liquid Global Rare Earth Companies (excluding China)						
[0;+1]	-0.79%	0.01%	-1.784*	-1.727*	-1.729*	158
[0;+3]	-0.77%	-0.26%	-0.772	-1.143	-1.144	158
[0;+5]	-0.70%	-0.19%	-0.541	-0.911	-0.913	158
[0;+10]	-1.11%	-0.78%	-1.234	-1.181	-1.182	158
[-5;+1]	-3.08%	-1.86%	-3.631***	-3.357***	-3.357***	158
[-5;+3]	-3.06%	-1.15%	-2.974***	-2.866***	-2.866***	158
[-5;+10]	-3.39%	-1.79%	-3.015***	-2.733***	-2.732***	158

(continued)

Table OA8: CAARs for Chinese REE Supplier, U.S. REE User, and Global REE Supplier and Refiner Companies After Extreme Price Events (± 2 and ± 1 standard deviations)—*continued*

Section 2	CAAR		Boehmer Test	t-Test	Johnson Test	
Event window	Mean	Median	t-value	z-score	J-value	Nobs
Panel A: Chinese REE Supplier Companies						
[0;+1]	0.45%	0.41%	1.629	1.512	1.513	280
[0;+3]	0.77%	0.28%	2.332**	2.095**	2.099**	280
[0;+5]	1.12%	0.38%	2.231**	2.118**	2.121**	280
[0;+10]	1.96%	1.37%	3.106***	2.703***	2.707***	280
[-5;+1]	1.46%	1.94%	2.907***	2.956***	2.961***	280
[-5;+3]	1.77%	1.30%	3.487***	3.453***	3.465***	280
[-5;+10]	2.96%	0.99%	4.246***	3.876***	3.882***	280
Panel B: Chinese REE Supplier Companies						
[0;+1]	-0.73%	-0.60%	-2.276**	-2.642***	-2.634***	252
[0;+3]	0.31%	-0.18%	0.745	0.766	0.767	252
[0;+5]	-2.07%	-1.97%	-3.641***	-3.759***	-3.764***	252
[0;+10]	-1.43%	-1.72%	-1.684*	-1.820*	-1.818*	252
[-5;+1]	0.55%	-2.58%	0.129	0.912	0.914	252
[-5;+3]	1.59%	-1.19%	1.483	2.187**	2.197**	252
[-5;+10]	-0.15%	-3.27%	-0.577	-0.138	-0.138	252
Panel C: U.S. REE User Companies						
[0;+1]	0.58%	0.35%	4.290***	3.707***	3.717***	1,967
[0;+3]	-0.56%	-0.49%	-3.291***	-2.092**	-2.087**	1,967
[0;+5]	-1.17%	-0.78%	-5.366***	-4.000***	-3.988***	1,965
[0;+10]	-1.09%	-0.12%	-2.772***	-3.063***	-3.068***	1,963
[-5;+1]	0.91%	0.59%	3.837***	3.193***	3.195***	1,967
[-5;+3]	-0.23%	-0.08%	-1.046	-0.595	-0.595	1,967
[-5;+10]	1.40%	0.46%	3.150***	3.102***	3.107***	1,963
Panel D: U.S. REE User Companies						
[0;+1]	0.08%	-0.15%	0.486	0.514	0.514	2,046
[0;+3]	0.12%	-0.21%	0.751	0.622	0.622	2,046
[0;+5]	0.28%	-0.31%	1.152	1.152	1.152	2,045
[0;+10]	-0.05%	-0.79%	-0.538	-0.147	-0.147	2,041
[-5;+1]	-0.26%	-0.36%	-0.895	-1.036	-1.035	2,045
[-5;+3]	-0.26%	-0.46%	-0.627	-0.939	-0.939	2,045
[-5;+10]	-0.50%	-1.08%	-1.416	-1.305	-1.305	2,040
Panel E: Global REE Supplier and Refiner Companies (excluding China)						
[0;+1]	0.71%	0.08%	2.337**	2.268**	2.272**	342
[0;+3]	2.23%	0.72%	5.257***	4.902***	4.918***	342
[0;+5]	2.12%	0.62%	4.076***	3.536***	3.549***	342
[0;+10]	3.33%	1.64%	1.278	3.774***	3.811***	342
[-5;+1]	0.52%	-0.49%	1.041	0.720	0.724	342
[-5;+3]	2.04%	-0.01%	3.364***	2.677***	2.699***	342
[-5;+10]	3.14%	1.06%	1.260	3.045***	3.065***	342
Panel F: Global REE Supplier and Refiner Companies (excluding China)						
[0;+1]	0.55%	0.06%	1.371	1.365	1.370	312
[0;+3]	-0.52%	-0.75%	-1.295	-0.910	-0.908	312
[0;+5]	-1.99%	-1.14%	-3.410***	-3.138***	-3.141***	312
[0;+10]	-0.91%	-0.97%	-1.673*	-1.173	-1.173	312
[-5;+1]	-0.19%	-0.24%	-0.530	-0.292	-0.291	312
[-5;+3]	-1.25%	-1.26%	-1.951*	-1.539	-1.537	312
[-5;+10]	-1.65%	-1.74%	-2.198**	-1.665*	-1.663*	312

Table OA9: Enlarged Tables 4 and 5 Including Firm-Level Controls

This table reports multivariate OLS regressions for five event windows using standard errors clustered on firm level (see Equation (1)). The dependent variables are the equally weighted *CARs* for Chinese REE suppliers and U.S. REE users (section 1—enlarged version of Table 4) and for Chinese and non-Chinese companies that are constituents of the Market Vectors Global Rare Earth/Strategic Metals Index (section 2—enlarged version of Table 5) in response to MOFCOM announcements from Table 1 (t_0) for various event windows applying a market model. The estimation period ranges from $t_0 - 120$ until $t_0 - 20$. Explanatory variables include a U.S.-dummy (1 if the *CAR* stems from a U.S. company) (section 1 only), a *China* dummy variable (1 if the *CAR* stems from a Chinese company) (section 2 only), and further control variables. Those control variables include industry fixed effects (not reported) and firm controls (size (ln(total assets), growth (percentage change in sales), return on equity (ROE) (income before extraordinary items divided by total equity), and leverage (debt divided by total equity). Growth, ROE, and leverage are winsorized at the 1% and 99% levels. Panel A reports results for all MOFCOM events; panel B reports results for *CARs* around events prior to the WTO dispute resolution case; panel C reports results for *CARs* around events post the WTO dispute resolution case. Nobs are the number of observations. Robust standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Dependent Variable: <i>CAR</i>					
Section 1	Event Window				
	[0;3]	[0;5]	[0;10]	[-5;3]	[-5;10]
Panel A: All Events					
US	0.002 (0.003)	0.010*** (0.004)	0.007 (0.005)	0.006 (0.005)	0.012* (0.007)
Size	0.000 (0.001)	-0.000 (0.001)	-0.003** (0.001)	0.002 (0.002)	-0.001 (0.002)
Growth	-0.001 (0.001)	0.002 (0.002)	0.002 (0.002)	-0.001 (0.004)	0.001 (0.004)
ROE	-0.001 (0.003)	-0.000 (0.005)	-0.003 (0.008)	0.002 (0.006)	0.001 (0.010)
Leverage	0.000 (0.000)	0.001 (0.001)	0.000 (0.001)	-0.000 (0.001)	-0.000 (0.002)
Constant	-0.009 (0.007)	-0.005 (0.011)	0.008 (0.012)	-0.041*** (0.014)	-0.023 (0.016)
Industry FE	Yes	Yes	Yes	Yes	Yes
Nobs	1,281	1,281	1,281	1,281	1,281
<i>F</i>	0.82	2.72***	5.53***	3.10***	3.18***

(continued)

Table OA9: Enlarged Tables 4 and 5 Including Firm-Level Controls—*continued*

Panel B: Pre-WTO Dispute Resolution Case					
US	-0.002 (0.004)	0.011* (0.006)	0.009 (0.008)	-0.001 (0.008)	0.010 (0.010)
Size	0.002** (0.001)	0.001 (0.001)	0.000 (0.002)	0.003 (0.002)	0.002 (0.003)
Growth	-0.000 (0.002)	0.001 (0.002)	0.002 (0.003)	0.002 (0.006)	0.005 (0.006)
ROE	0.000 (0.004)	-0.002 (0.007)	-0.010 (0.013)	-0.000 (0.008)	-0.011 (0.015)
Leverage	0.002 (0.001)	0.004* (0.002)	0.002 (0.002)	0.002 (0.002)	0.002 (0.002)
Constant	-0.010 (0.009)	-0.010 (0.013)	-0.016 (0.019)	-0.037* (0.020)	-0.043 (0.026)
Industry FE	Yes	Yes	Yes	Yes	Yes
Nobs	630	630	630	630	630
<i>F</i>	2.35**	12.41***	3.54***	2.91***	6.11***
Panel C: Post-WTO Dispute Resolution Case					
US	0.005** (0.003)	0.008* (0.004)	0.005 (0.006)	0.013** (0.005)	0.012* (0.007)
Size	-0.001 (0.001)	-0.002 (0.001)	-0.006*** (0.002)	0.002 (0.002)	-0.004 (0.002)
Growth	-0.001 (0.001)	0.003 (0.004)	0.001 (0.003)	-0.009*** (0.002)	-0.007*** (0.002)
ROE	-0.003 (0.005)	0.004 (0.008)	0.012 (0.010)	0.006 (0.011)	0.021 (0.013)
Leverage	-0.002** (0.001)	-0.004 (0.003)	-0.003 (0.003)	-0.004* (0.002)	-0.006* (0.003)
Constant	-0.011 (0.011)	0.006 (0.017)	0.040** (0.020)	-0.049*** (0.015)	0.002 (0.022)
Industry FE	Yes	Yes	Yes	Yes	Yes
Nobs	651	651	651	651	651
<i>F</i>	2.75***	1.73*	16.98***	4.10***	25.61***

(continued)

Table OA9: Enlarged Tables 4 and 5 Including Firm-Level Controls—*continued*

Dependent Variable: <i>CAR</i>					
Section 2	Event Window				
	[0;3]	[0;5]	[0;10]	[-5;3]	[-5;10]
Panel A: All Events					
China	0.030*** (0.008)	0.030*** (0.010)	0.031** (0.012)	0.027* (0.015)	0.028 (0.017)
Size	-0.002 (0.004)	-0.001 (0.005)	0.013** (0.005)	-0.004 (0.002)	0.011** (0.005)
Growth	-0.002 (0.002)	0.001 (0.004)	-0.002 (0.004)	-0.006* (0.003)	-0.005 (0.004)
ROE	0.037** (0.017)	0.031 (0.025)	0.004 (0.021)	0.047 (0.034)	0.014 (0.036)
Leverage	-0.002 (0.003)	-0.004 (0.004)	-0.017 (0.010)	0.005 (0.006)	-0.010 (0.010)
Constant	0.030 (0.057)	0.025 (0.067)	-0.168** (0.072)	0.051 (0.035)	-0.147** (0.063)
Industry FE	Yes	Yes	Yes	Yes	Yes
Nobs	242	242	242	242	242
<i>F</i>	2.96***	1.64	0.78	1.91*	0.65
Panel B: Pre-WTO Dispute Resolution Case					
China	0.036*** (0.008)	0.043*** (0.014)	0.047*** (0.014)	0.044* (0.021)	0.055* (0.029)
Size	0.000 (0.006)	-0.002 (0.006)	0.011* (0.006)	-0.000 (0.005)	0.010 (0.006)
Growth	-0.008 (0.008)	-0.014 (0.008)	-0.010 (0.012)	-0.012 (0.009)	-0.013 (0.015)
ROE	0.014 (0.041)	0.037 (0.048)	0.020 (0.050)	-0.026 (0.058)	-0.020 (0.062)
Leverage	-0.008 (0.006)	-0.009 (0.008)	-0.014* (0.008)	-0.009 (0.008)	-0.015 (0.011)
Constant	0.012 (0.082)	0.058 (0.082)	-0.142* (0.081)	0.010 (0.071)	-0.144* (0.078)
Industry FE	Yes	Yes	Yes	Yes	Yes
Nobs	127	127	127	127	127
<i>F</i>	1.56	1.75	1.32	1.53	1.19

(continued)

Table OA9: Enlarged Tables 4 and 5 Including Firm-Level Controls—*continued*

Panel C: Post-WTO Dispute Resolution Case					
China	0.021 (0.013)	0.017 (0.013)	0.016 (0.020)	0.005 (0.018)	0.000 (0.023)
Size	-0.003 (0.006)	0.006 (0.005)	0.007 (0.010)	-0.005 (0.008)	0.005 (0.012)
Growth	-0.001 (0.002)	0.006 (0.005)	-0.001 (0.004)	-0.005 (0.003)	-0.005* (0.003)
ROE	0.050** (0.020)	0.017 (0.027)	0.020 (0.021)	0.103*** (0.025)	0.073* (0.036)
Leverage	0.003 (0.004)	-0.002 (0.004)	-0.019 (0.024)	0.010 (0.008)	-0.012 (0.021)
Constant	0.039 (0.081)	-0.086 (0.065)	-0.067 (0.137)	0.067 (0.113)	-0.039 (0.166)
Industry FE	Yes	Yes	Yes	Yes	Yes
Nobs	115	115	115	115	115
<i>F</i>	2.14**	1.17	0.16	2.47**	0.38

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