



# China's public policies toward rare earths, 1975–2018

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## Abstract

This paper summarizes and evaluates China's policies toward the rare-earth industry from 1975 to 2018. We define five stages over this period and focus on China's purpose, the underlying economic background in each stage, and the connections between stages. By reviewing a broad set of original policy documents, we find that the purpose of China's policies has evolved, affected by the market players, the development of the mineral industry, and the state of the Chinese economy. Initially, the Chinese government encouraged the development of the upstream rare-earth sector. Since the early 1990s, China has focused on the development of downstream activities that use rare earths in the manufacture of intermediate and final products. Since the early 2000s, China has focused additionally on the problems of disorder in the rare-earth industry with particular reference to the environmental degradation caused by rare-earth production, as well as industrial reorganization to discourage unsanctioned production.

**Keywords** Rare earths · Public policy · China · Illegal mining

## Introduction

Rare-earth elements are essential to the modern economy, providing essential properties to magnets in high-efficiency motors, to phosphors in lighting, and to catalysts in a variety of chemical activities, among other important applications. In 2010, China cut its production quota for rare-earth (RE) concentrates by 25% and its export quotas for various RE products by 37% (MIIT 2009-2011; Roskill 2015). As China was producing most of the RE minerals in the world, these actions caused a sharp increase in the RE prices. For example, the Chinese-export price of neodymium oxide increased from approximately \$25/kg in early 2010 to a peak value of \$340/kg in July 2011 (Fig. 1). Prices of all REs followed a similar pattern during this period (Argus Media, 2018). The sharp and significant increase in prices drew worldwide attention to this market and raised questions about the supply security

of RE products. In this study, we focus on the underlying factors that drove China's tightened RE policies and, more broadly, the development of the Chinese RE policies between 1975 and 2018. Further, we are interested in the most recent policies to anticipate future developments.

China began to dominate the supply of RE concentrates and separations in the early 1990s when its total production of upstream and midstream products accounted for more than half of global RE production (Fig. 2). China's share of supply increased from 21% in 1985 to the recorded high of 97% between 2005 and 2011. In 2018, the share shrank to 71% but would be higher if we consider undocumented and illegal production.<sup>1</sup> China's RE reserves are about 44 million tonnes,<sup>2</sup> which account for 37% of world reserves (USGS 2017). Moreover, with China's unprecedented economic growth, industrialization, and policy incentives, its consumption of RE oxides, metals, compounds, and alloys in manufacturing also increased from 4888 t REO in 1987 to 19,270 t in the early 2000s, and further to around 125,000 t in 2018 (Su 2009; Tse 2011; Kingsnorth 2016 and 2019).

Considering China's substantial influence on the entire RE supply chain, consumers and potential producers in the rest of

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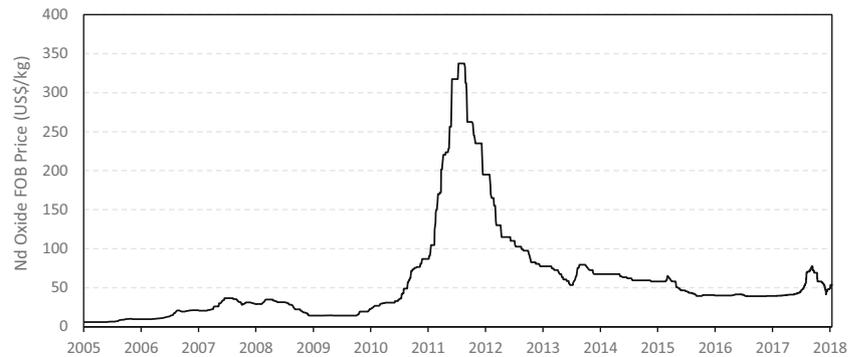
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<sup>1</sup> Illegal production is defined here as the quantities of mining and processing products that exceed the quota issued by the Chinese government. Other laws and regulations are not considered for defining the quantity of illegal production.

<sup>2</sup> 1 t = 1 metric ton = 1000 kg.

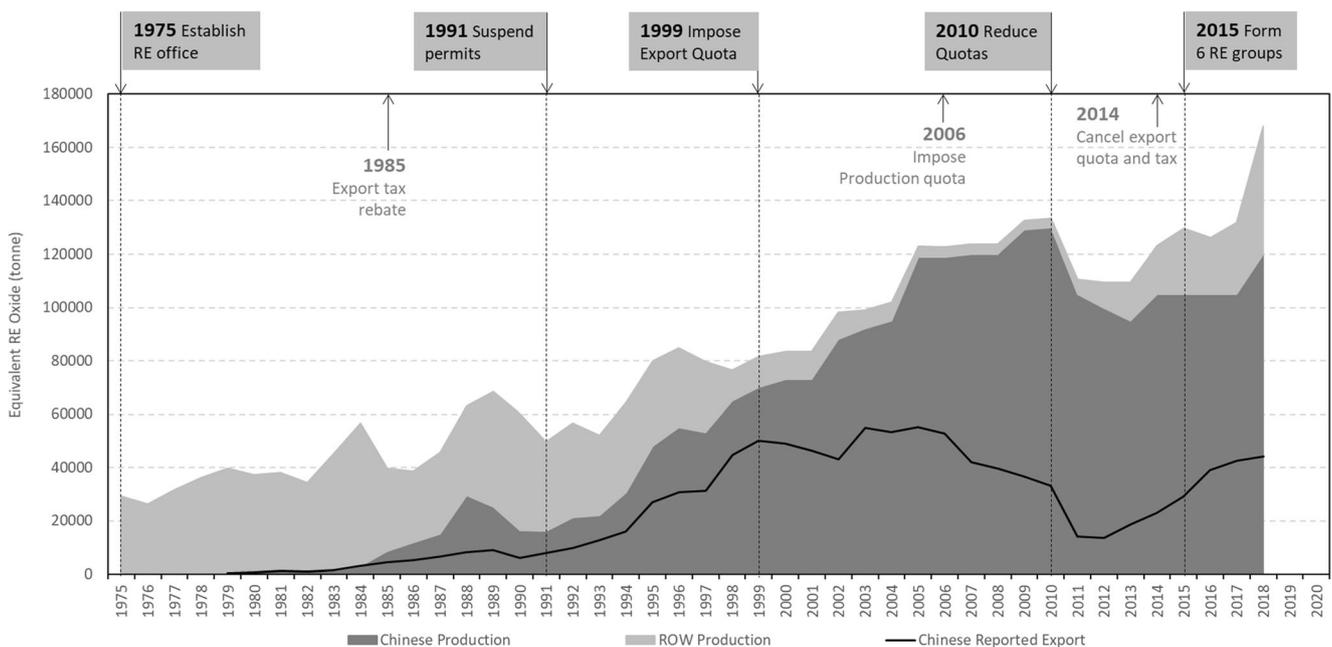
**Fig. 1** Chinese neodymium oxide export price. Source: Argus Media (2018)



the world started to consider possible RE deposits outside of China and undertook research to substitute away from RE elements in engineered systems and products. Studies on China's RE policies appeared. Some research asked questions similar to those we ask in this paper. For example, Wübbecke (2013) uses three narratives to explain the evolution of China's RE policies, including geopolitical, environmental, and development perspectives. He notes that it is important to understand China's RE policies systematically—that is, export restrictions, the most controversial policies, need to be considered in light of other policies and regulations in the Chinese economy including “industrial reorganization, resource conservation, and environmental protection.” Wübbecke concludes that, in the long-term, export controls

are driven by the Chinese domestic concerns about the entire industrial chain. Two books in Chinese, Su (2009) and Yang (2015), provide useful insights into China's RE industry and policies. Both works describe the evolution of the RE industry in China and internationally, analyze the problems China is facing, and provide policy suggestions for the Chinese government.

Other research focuses on a single topic. Morrison and Tang (2012), from the Congressional Research Service of the United States, study the impact of a wide range of China's RE policies on the supply chain, including consideration of whether China's restriction on RE exports hurts the interest of US firms and consumers. Yang et al. (2013) study environmental damage due to the outdated and illegal mining



**Fig. 2** Chinese and Rest-of-World Mine Production of Rare Earths, and Chinese Exports. Sources of production data: USGS (1987–1997) and USGS (1996–2019). Data are measured in tonnes of equivalent RE oxide. See the USGS documents for more information. Note that after 2014, USGS use the official Chinese production quota as the quantity of production (USGS 2014). Chinese production for 1979 to 1984 is approximated using Chinese export data from Liu (2014). For exports, the data

for 1979 to 2008 are from Liu (2011). The data for 2009 to 2016 are approximately converted from data measured in tonnes of gross RE products from various sources: Lin (2001), Roskill (2007), Roskill (2011), Wang (2012), Chen (2014), Chen and Xu (2015), Chen and Du (2016), and Chen (2019). Total Chinese RE exports from 1973 to 1978 are 150 t (Su 2009, p151) and are not reflected in the figure

of RE ionic clay in southern China. Liu (2016) has the same concerns about illegal production and the resulting pollution in China—nationally rather than just in southern China. Packey and Kingsnorth (2016) analyze the negative externalities of illegal mining not only on the environment but also on international markets as RE prices have not been sufficiently high and stable to encourage the development of mines outside of China, increasing the RE dependency of the rest of the world on China. Chen et al. (2015) estimates the size of illegal mining and provides regulation suggestions for the Chinese government. Nguyen and Imholte (2016) present a system-dynamic model to estimate illegal production. Other studies focus on China's export controls (see, for example, Zhong and Liang 2012; and Mancheri 2015). Han et al. (2016) use theoretical game-theory models to show that profit-maximizing RE firms prefer horizontal integration, while the social welfare maximizing Chinese government prefers vertical consolidation.

This study makes three contributions. First, instead of describing each type of policy and its purpose and motivation separately, we exam the policies together in each of five stages. The policies in each stage relate to one another in terms of purpose and impact and should be evaluated together—and with knowledge of the Chinese mineral industry and the economy overall. The continued existence of illegal mining and processing and the weak implementation of some policies

(especially environmental) reflect the overall situation of the Chinese mineral industry. In fact, the policies reflect the characteristics of the overall economy in terms of development (Yang 2015, p242). Moreover, describing China's purpose throughout the entire period of interest ignores the interaction between the players in the RE market and the policy makers. Our analysis reveals the influence of policies and the market from the previous stage(s) on the later stage. Second, we review and document a broad set of Chinese RE policies and support the arguments with details and accurate information from the original documents. Third, we include updated data and information, compared to previous studies. As the RE market is opaque and much public data are simply approximations, we assemble historical data from various sources to illustrate market trends.

We find two underlying reasons driving China's increasingly tightened RE policies. The first is the desire for economic growth and maximizing the returns from the development of China's rich endowment of rare earths: China encouraged the development of downstream activities that would create more added value than the upstream sector alone. The expansion of downstream manufacturing using Chinese REs was facilitated by the expansion of the Chinese economy overall. Restrictive export policies allowed Chinese users of REs to benefit from lower prices than foreign customers. Second, the sustained, tightened policies have been motivated by

**Table 1** Chinese rare-earth policy catalog. See Appendix for more detailed information on each type of policy. The intervals represent a policy's starting point and either the ending point or 2018 for those policies still in effect. The time line is not drawn to scale

Policy Type	Sub-group	1975-1990: Upstream Production for Export	1991-1998: Initial Restrictions on Production & Foreign Investment	1999-2009: Export Quotas & Taxes, Downstream Promotion	2010-2015: Further & Broader Restrictions, WTO Dispute	2016-2018: Post WTO Dispute
RE Office		----- ----- ----- ----- -----				
Industrial policy	Foreign Investment	----- ----- ----- ----- -----				
	Production Quota	----- ----- ----- ----- -----				
	Regulations of Production Quota	----- ----- ----- ----- -----				
	Industrial Consolidation	----- ----- ----- ----- -----				
	Product Tracing System	----- ----- ----- ----- -----				
	Exploration and Mining Permit	----- ----- ----- ----- -----				
	Crackdown on Illegal Production	----- ----- ----- ----- -----				
	Industrial Standard	----- ----- ----- ----- -----				
Export policy	Development Plan	----- ----- ----- ----- -----				
	Export Quota	----- ----- ----- ----- -----				
	Export Tax Rebate	----- ----- ----- ----- -----				
	Export Tax	----- ----- ----- ----- -----				
Environmental policy	Export Permit	----- ----- ----- ----- -----				
	Emission Standard	----- ----- ----- ----- -----				
	Land Restore	----- ----- ----- ----- -----				
	Laws and Regulations	----- ----- ----- ----- -----				
Resource Tax	Qualified RE Firms	----- ----- ----- ----- -----				
		----- ----- ----- ----- -----				

conflict between the desires for both economic growth and sustainable development. As we will see in the following sections, the Chinese central government noticed the problems of illegal mining and environmental damages caused by RE production as early as the 1990s. Efforts at treating these problems were not successful in the early period because the central government itself had difficulties reconciling or balancing desires for both economic growth and sustainable development. As the priority for environmental quality and industry order increased over the period of study, we see the stricter policies on environmental protection and resource conservation. But most of these policies have to be implemented by local authorities who do not always want to comply. China has a geographically imbalanced economy. The natural resource-rich areas generally are less developed economically compared to the east-coast provinces. Economic growth is still the first priority of local governments, even when the policy makers in Beijing are considering policy transformation.

The rest of the paper is organized around five stages in the evolution of Chinese policies toward rare earths (Table 1). The analysis starts in 1975, when Chinese RE production became non-negligible and, additionally, the Chinese government established the National Rare Earth Development and Application Leading Group, the first indication of central-government interest in the sector. To reduce confusion, we simplify the entire RE production process and define the corresponding products in Fig. 3. Upstream or primary products are RE ores and concentrates. Midstream products include separated RE oxides, metals, and alloys. The downstream sector represents users of midstream products for the manufacture of RE-containing products. Figure 12 to Figure 18 in the Appendix show short summaries of policies in timelines by policy type and serve as a complement to the text in the main body of the paper.

## 1975–1990: promotion of upstream production for export

Although China started to develop the technology of extraction, separation, smelting, and further processing of RE minerals in the late 1950s, it was not until the mid-1970s that China became able to make quality RE products and “emerged as a very important producer, consumer, and exporter” of RE materials (BoM 1975–1985). China started to export mixed RE chlorides in 1973. However, the total amount of exports from 1973 to 1978 was merely 150 t (Su 2009, p. 151). In about 1980, Japan increased the import of RE products from China from some 1000 to 2000 t of primary RE chlorides and oxides (Zhou 1984). The major China-Japan RE trade products were primary mixed RE materials; at that time, Japan had strong separation capacity with low cost (Zhang 1983). The USA imported a similar amount of RE

chlorides from China starting in the early 1980s. By 1985, China’s capacity for producing mixed RE chlorides and oxides was approximately 10,000 t (BoM 1975–1985).

The Chinese central government started to regulate the RE industry in 1975 when it established the National Rare Earth Development and Application Leading Group (Hong 2015), hereinafter referred to as the RE office.<sup>3</sup> Between 1975 and 1990, the primary purpose of China’s RE policy was encouraging the development of the infant RE mining industry. Domestic consumption alone was not sufficient to support much growth in the industry. To spur the industry and accumulate foreign reserves, China attempted to expand the export of RE products. In 1985, RE exports became eligible for export-tax reimbursement so that RE firms enjoyed the rebate of the export-product tax or the added-value tax (State Council 1985). According to Tang (2017), the tax-rebate rates for RE ores and RE metals were 13% and 17% respectively. The refund of export tax significantly stimulated the RE upstream production. From 1985 to 1990, China’s RE minerals production doubled from 8500 t of REO to 16,500 t with an annual growth rate of 14% (Fig. 2).

In late 1989 and early 1990, Rhone-Poulenc (later Rhodia, then Solvay) was denied an extension of its radioactive waste disposal license at its processing plant in La Rochelle, France. As a result, this accelerated the move of its extraction and solvent-extraction facilities to China. At the same time, Japan was closing down many of its rare-earth processing facilities and transferring plant and technology to China—in exchange for supply contracts. These transfers greatly assisted development of China’s upstream sector and subsequent moves downstream.

In this stage, the Chinese upstream industry was profitable, reflecting low production costs relative to market prices and the absence of administrative regulations. The central government found it difficult to regulate the RE industry uniformly. Quickly, due to significant competition among the large number

<sup>3</sup> The functions of this office have resided in a number of institutional entities within the central government. Here are all of the entities that have come to exercise authority over the RE industry since 1975. In 1988, to further regulate and guide the production, application, and export of RE minerals, China established the RE Leading Group and the corresponding office under the State Council (Hong 2015; Ren 1988). Between 1995 and 2002, the State Development Planning Commission took charge of RE affairs. In 2003, with the reform of administrative departments, the State Development Planning Commission was renamed the National Development and Reform Commission (NDRC), and the RE office was reinstated under the NDRC. In 2008, all of the functions of industrial regulations and the management of the State Tobacco Monopoly Bureau broke away from the NDRC and formed the Ministry of Industry and Information Technology (MIIT). The RE office moved to MIIT during this reform. The main duty of the RE office and MIIT is carrying out RE regulations on the midstream sector and coordinating actions among ministries and departments within the State Council. In addition, the Ministry of Land and Resources (MLR) manages mining permits, and the Ministry of Commerce (MOFCOM) is in charge of export quota and permits (Yang 2015, pp. 268–269). The policy documents reviewed for this paper largely come from the ministries above.

of Chinese RE producers, RE prices fell dramatically despite increasing demand. Problems arose quickly; for example, illegal production became common in this disordered stage (State Council 1991). As illegal production added to supply, it put downward pressure on prices, especially as illegal production had lower costs from avoiding taxes and neglecting environmental standards. In 1994, Chinese RE producers attempted to stabilize the price by collusion (Su 2009, p106).

### 1991–1998: initial restrictions on production and foreign investment

With the booming RE industry and the associated issues of low prices, illegal producers, and disorder in the sector, the Chinese central government began to realize the importance of RE minerals, their corresponding strategic value, and the urgency of addressing these issues. First, China started to restrict foreign investment in the early 1990s, especially in the upstream sector. All foreign investment in the RE industry had to be approved by the RE office. Foreign investors had restricted access to RE exploration, mining, beneficiation, smelting, and separation. Foreign investment could not be involved in any projects that damaged the environment and natural resources (RE office et al. 1990; SPC and MFTEC 1995a, 1995b, 1997).

Second, beginning in 1991, exploration and mining licenses were frequently suspended. During most of the time, China only renewed licenses for qualified firms and only issued licenses for government-involved exploration.<sup>4</sup> Suspension of mining licenses was one of the direct administrative measures to tackle the government's perception of the over-investment problem, yet it could only affect the firms that complied with government regulations.

Third, in 1991, with the observation of illegal mining and wasting of RE resources, China specified the ionic clays as “national protective exploitation minerals” that should be regulated by the central government for all of the stages of the supply chain. Specifically, the RE office was in charge of middle to long-term ionic clay resource development and planning. State-owned mining enterprises<sup>5</sup> approved by the RE office had priority to develop RE ionic clays. Enterprises with collective ownership<sup>6</sup> could only mine small and low-grade reserves. Private enterprises were not allowed to participate in the industry. The RE office would develop production plans for ionic-type RE concentrate and smelting products. Collective-owned and privately owned firms could not be involved in ionic-type RE separation and smelting. Lastly,

<sup>4</sup> See Figure 13.

<sup>5</sup> State-owned enterprises are owned by the nation and supervised by either the central government (state council) or local governments.

<sup>6</sup> Collective enterprise, a socialist term, is different from state-owned enterprise and refers to enterprises owned by all of their workers rather than the nation.

the RE office would plan all of the domestic trade (State Council 1991). Even though the regulations look strict, the enforcement was not entirely successful. In particular, illegal mining of ionic clays in southern China remained a problem.

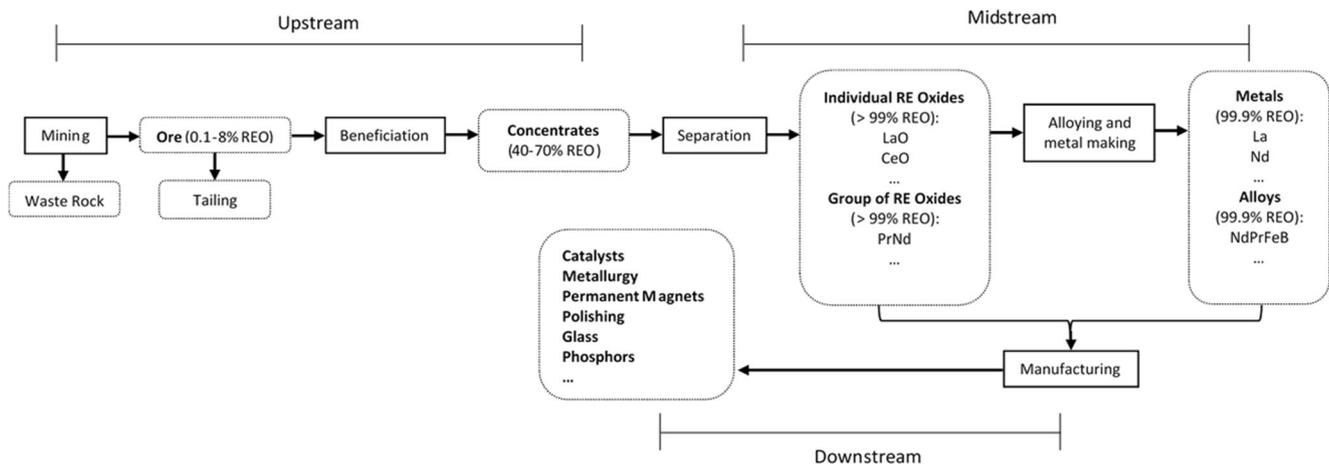
Despite the increased control that these policies gave to the government, this historical stage experienced the fastest growth in RE minerals production. The total production increased from 16,150 t in 1991 to 65,000 t in 1998, an annual growth rate of 22%. Meanwhile, China's market share of RE minerals went from 33 to 85% (Fig. 2). Production and exports still benefited from export tax reimbursement.

### 1999–2009: substantial restrictions on production and exports, and promotion of downstream use

The problems caused by the strong development of the RE industry in the first historical stage were far from solved and, very likely, became worse after the rapid growth during the 1990s. The main conflict was between advocating for economic growth on one hand, and environmental and resource considerations, on the other. Obviously, within the central government, economic growth had dominated policy in the earlier stage. At the third historical stage, the top policy makers noticed the problems and started to think about environmental and resource sustainability; however, local entities did not completely share these objectives. The central government introduced export quotas, production quotas, and export taxes on RE products and further tightened the restrictions on foreign investment. Those policies had the direct effect of encouraging domestic downstream development by giving the Chinese domestic firms the advantage of cheaper raw RE materials and driving foreign firms to move their processing operations to China.

#### Export quotas

To control total production and illegal activities at the border of the country, in 1999, China introduced the export quota, the most influential regulations on the RE international market (MFTEC 1999a, 1999b, see Fig. 4 for the export quota of each year from 1999 to 2014). In addition to shrinking the amount of RE exports, China put specific restriction on the structure of export quotas to support the development of the downstream sector (Tse 2011). First, the central government encouraged the local authorities to issue quotas to the firms that could create high added values and medium- to large-scale state-owned firms. Second, in 2000, the quota for primary products, chlorides, decreased, while the quota for oxides and metals increased, and magnetic materials were not regulated by quota at all. Later, China kept the strict



**Fig. 3** Rare-earth flow chart. The solid rectangles represent the processes, and the dashed rounded rectangles represent the products from the previous process and the inputs for the next process

restrictions on primary-product exports and facilitated the export of more advanced products. Third, China issued the quotas based on the firms' conditions of environmental qualification (Zhang 2014).

### Production quotas

Another policy that had direct impact on the supply chain was the production quota—on RE concentrates introduced in 2006 by the Ministry of Land and Resources (MLR), and a separate quota on RE concentrates and separations introduced in 2007 by the National Development and Reform Commission of China (NDRC) (see Fig. 5 for the two sets of quotas). In 2009, the latter one was issued by the MIIT as the RE Office was moved to MIIT from NDRC; therefore, we call this quota the MIIT quota. The MIIT quotas were directly applied to individual firms, and after 2016 the quotas were allocated to the six state-owned RE groups. Each group has the right to assign the quota and the responsibility to report to the local MIIT and then the central government. The MLR, however, assigns the quotas to each province, although it is the case that the production in many provinces is dominated by a single RE group. From 2012, both the MIIT and the MLR began to release the quota in two rounds (MLR 2012a; MIIT 2012a). MIIT issues quotas in the beginning and the middle of a year, and the summation of the two quotas is the total amount for the year. MLR has a similar time scheme, while the quantity of the second quota covers the first one. Before 2010, the two ministries assigned two quotas with large discrepancy. The two sets of quotas converged in 2010 and, combined with the process of merging the RE firms into the six groups, the confusion regarding the quota vanished gradually.

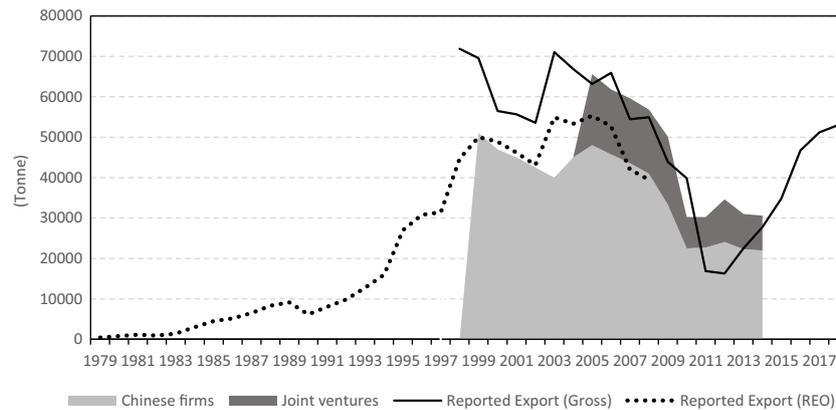
### Industrial order, more restrictions on foreign investment, and export taxes

The document “Notice on Rectification and Standardization of Development Order of Mineral Resources” was a general and vital administrative notice for reorganization of the entire mineral industry (State Council 2005). It states that with the dramatic development and exploitation, the mineral industry was suffering from problems such as poor management, resource wasting, environmental damage, and production safety accidents. In addition, illegal exploration and mining were still a problem during this period. The document specifically stated the requirements for the RE industry that the Ministry of Land and Resources together with other ministries, such as NDRC, the Ministry of Commerce (MOFCOM), and MIIT, were responsible for the rectification of mining, beneficiation, separation processing, and trading of RE products. Further, according to this document, MLR started to set RE production quotas, as discussed in the “Production quotas” section, and inspect the implementation of the quota (State Council 2005). The shrinking export quota and the introduction of production quotas together with the central government's intention to reorganize the industry make 2006 a special year. Other policies also became constrictive around 2005 to 2006.

China further limited foreign investment in this stage. Starting in 2002, only joint-venture RE smelting and separation enterprises were allowed but no wholly foreign-owned enterprises in the RE mining sector. However, it is worth noting that China consistently encouraged foreign investment in the RE downstream processing sector beginning in 1990<sup>7</sup> (NDRC and MOFCOM 2002, 2004, 2007; SPC 2002).

From 2004, the export-tax reimbursement for RE ores, metals, and oxides, the policy that accelerated the

<sup>7</sup> See Figure 12 for more information.



**Fig. 4** China's rare-earth export quota (Stack) and total reported export (Lines). For export quota, shown by the stacked area and measured in tonnes of gross weight of RE products, the data of 1999 is from the Ministry of Foreign Economic Relations and Trade of China (1999b), the data of 2000–2004 is from Tse (2011), and the data of 2005–2014 is from Roskill (2015). The export quota was assigned to domestic producers and Sino-foreign joint ventures separately. The quota for domestic firms decreased gradually from 51,074 t of RE oxide in 1999 to 33,300 t

in 2009. The export quota data for Sino-foreign joint ventures are only available since 2005 and were stable until 2010. The solid line indicates the reported Chinese RE export, measured by tonnes of gross RE products, based on various sources: Lin (2001), Roskill (2007), Roskill (2011), Wang (2012), Chen (2014), Chen and Xu (2015), Chen and Du (2016), and Chen (2019). The dash line, however, indicates the reported export in terms of REO according to Liu (2011)

development of the industry in the 1990s, was gradually reduced and finally canceled. According to MoF and SAT (2003), RE ore export would not be eligible for tax refund. For RE metals, yttrium and scandium, the tax refund rate decreased to 5%. In 2005, China canceled the tax reimbursement scheme for all RE metals and oxides (MoF and SAT 2005). Following the trend of restraining RE export, from 2007, China started to levy export taxes at the rate of 10% for all RE ore, oxides, compounds, and so on. In 2008, the tax rate rose to 15% and 25% for different elements and products. As you will see in the next stage, in 2010, China imposed an export tax on the end-use-product NdFeB alloy that was not used for permanent magnets. In 2012, China started to tax NdFeB rapid-setting permanent magnet slices (MoF 2006, 2007a, 2007b, 2008, 2009, 2010, 2011, 2012. See Fig. 15 for details). The stricter export taxes were aimed at incentivizing the downstream sector, restricting RE production, and protecting the nonrenewable resource. However, the taxes imposed on legal firms created even higher profit margins for illegal firms (Zhong and Liang 2012). The export tax discouraged legal exports of less-processed RE and contributed to the transformation of the structure of the Chinese RE industry: while the total quantity of exports decreased after 2005, the portion of further processed RE products increased (Wang and Hong 2012).

The results of the policies during this stage were (1) the export quota contributed to the decline of exports from 69,547 t in 1999 to 63,149 t in 2005; (2) subsequent and further export restrictions—plus the production quota and industrial reorganization, the stricter requirements for foreign investors, and the export tax—caused China's RE

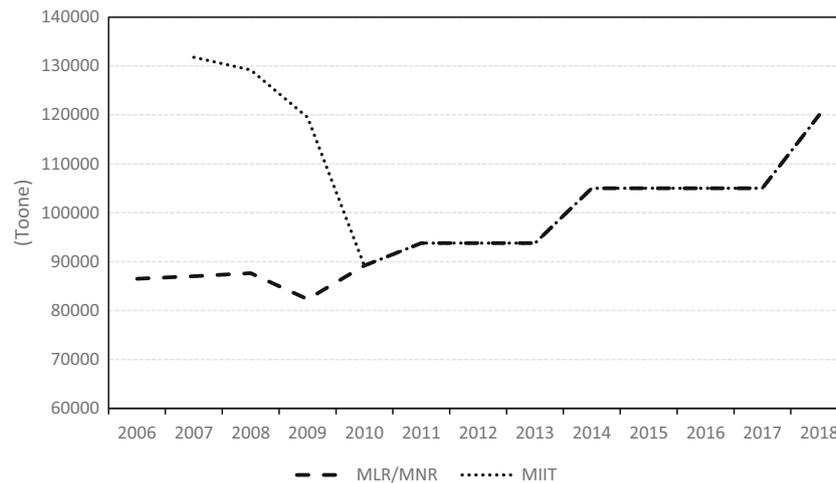
exports to drop significantly to 43,918 t in 2009 (Fig. 4); (3) production growth slowed as well, from 9.25% annually during the period 1999–2005 to approximately 2% annually during the period 2005–2009 (Fig. 2); and (4) growth in domestic consumption of primary and mid-stream RE products by downstream customers accelerated (Fig. 6).

## 2010–2015: further and broader restrictions and the World Trade Organization dispute

Although production and documented exports had been somewhat controlled, illegal producers remained active. In this historical stage, China tightened its RE quotas and introduced specific policies on environmental protection and illegalities. We discuss illegal mining and smuggling first and then move to the policies and reaction of international RE customers.

### The impact of production quotas and illegal mining—some success

Although a production quota would seem to be the most direct way to influence output, enforcement of the quota was incomplete. Not surprisingly, the Chinese central government was aware of the problem for quite a while. In 2012, the Chinese government released the “Interim Measures for the Administration of RE Mandatory Production Plan” and the “Measures for the Administration of Total Mining Quota” to enhance the implementation of the production quota and control the total amount of RE products on the market (MLR 2012b; MIIT 2012b). Stockpiling was one



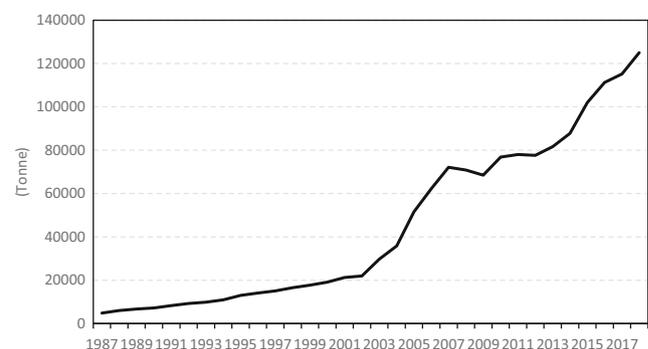
**Fig. 5** Chinese rare-earth production quota. The data are in metric tons of RE oxide. The MLR quota is for concentrates and is specified for light RE and middle-heavy RE. The MIIT quota is specified for separation and concentrate. The data used in the figure are for concentrate. Data sources: MIIT (2009–2011, 2012a, 2016a, 2016b, 2017a, 2017b), MLR (2006–2009, 2010, 2011, 2012a, 2013–2015, 2016a, 2017), MIIT and MNR

(2018a, 2018b), and MNR and MIIT (2018). The MIIT quotas in 2007, 2008, and 2013 are from Roskill (2015). As the MIIT quotas for 2014 and 2015 are not available, we assume that from 2010 MLR and MIIT have the same quota for RE concentrate. The Ministry of Natural Resource (MNR) of China was established in 2018, which incorporated the former MLR. Since then, MIIT and MNR jointly announce their quotas

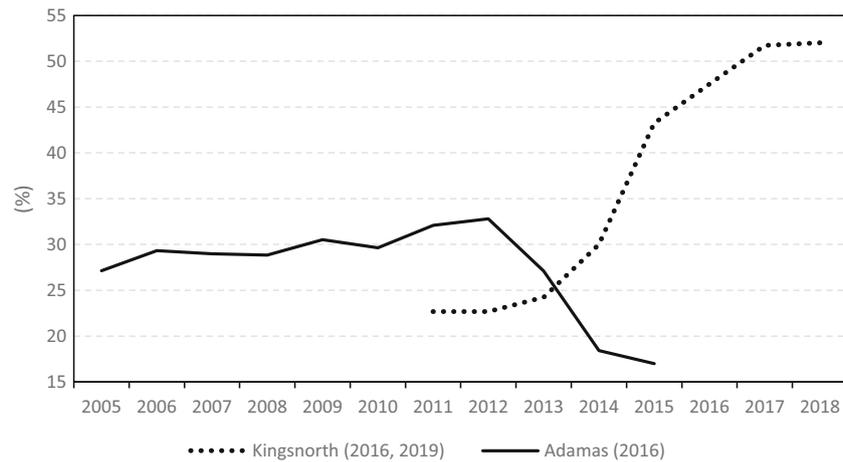
method the Chinese central government employed to deal with production created by the illegal operators. In 2014, the State Reserve Bureau of China purchased 10,090 t of RE products from the six largest RE firms and required the firms to further stockpile 30% of the amount sold to the government.

Published research tells very different stories about the size of illegal production. Figure 7 shows the ratio of Chinese illegal RE production to the total production from two studies. Adamas (2016) claims that the illegal production was about 30% of total production between 2005 and 2012 and dropped below 20% after 2014. This estimation supports the claim that the China's RE regulation was effective and illegal activities were falling. Kingsnorth (2016, 2019) largely diverges from this estimation. He states that the illegal-sector production was equivalent to about 23% of total production before 2013, but increased drastically above 50% after 2017—implying that China's policies failed to curtail the illegal production at all. Nevertheless, all the estimates support the theory that illegal upstream and midstream operators provided substantial cheap primary inputs to the downstream sector. Packey and Kingsnorth (2016) study the illegal mining of ionic clay deposits and estimate the illegal sector to be the equivalent of about 40% of legal production. They also assert that illegal mining not only reduced the profitability of the legal firms but also damaged the ecology substantially as illegal firms did not treat environmental damage and evaded taxes and fees. Moreover, illegal mines typically only take the high-grade reserves rather than optimizing the profit of the entire reserves.

Packey and Kingsnorth (2016), and others, note that local governments cooperate with illegal RE mining. Frequent explanations for this cooperation are that the localities benefit from more local employment and taxes than otherwise would exist. These two benefits may not provide sufficient explanation for the cooperation with illegal producers because, first, local officials arguably are not too concerned about the employment rate, and second, there is no incentive for illegal miners to pay resource and value-added taxes and administrative fees (CCDI 2014). There are three more likely reasons that explain the cooperation between illegal sector and local government. First, the illegal mining sector contributes to the local economy in terms of GDP—not directly, as illegal production is not likely counted into the local GDP directly, but rather indirectly as illegal rare-earth products



**Fig. 6** China RE consumption. Measured in tonnes of REO. The series is aggregated from the data provided in Su (2009), Tse (2011), Roskill (2015), Kingsnorth (2016), and Kingsnorth (2019)



**Fig. 7** Chinese illegal RE production as a share of total production. The estimation of Kingsnorth (2016, 2019) is based on the RE elements shortage in the Chinese domestic RE magnet industry. As noted by Zhanheng Chen, who is the Deputy Secretary of the Association of Chinese Rare

Earth Industry, illegal production is mainly driven by the demand for RE magnets. Adamas (2016) estimates the legal and illegal production for each element separately. The estimated legal production from Adamas (2016) is very close to the MLR quota

enter the supply chain for legal downstream products<sup>8</sup> (Packey and Kingsnorth 2016). Second, the development of the RE industry as a key industry contributes to the promotion of local officials. With the high RE prices after 2011, local governments in the areas of rich RE resources planned RE processing industrial zones that compete with each other. These flourishing midstream to downstream sectors demand raw materials in greater quantities than the official quotas. The third plausible reason is corruption. Local officials take cash bribes from the illegal owner, or the local officials invest in the illegal mining directly and earn dividends.<sup>9</sup> Besides, to generate government

revenue, local officials leased state-owned forestlands for illegal mining (CCDI 2014).

The separation of ownership and the extraction right causes firms and local governments to have different objectives from those of the central government. Therefore, firms do not follow production and export regulations as expected. One may argue that the excess production comes from illegal firms without mining permits; however, illegal products will go to legal firms somewhere in the supply chain and the products become legal gradually. Therefore, the local government selectively ignores the illegal mining and the legal firms finally digest the illegal products and contribute to the local economy.

The demand from downstream processors for the mid-heavy REs was not being met with the existing production quotas, and thus illegal producers filled this gap. An increase in the production quota would decrease the motivation for illegal production. The complexity of the composition of RE deposits contributes to the challenges of allocating production quotas. Rare earth elements (of which there are 17) occur in ore deposits tightly bonded together and in varying proportions. For example, the deposits in the north have a relatively large proportion of the lower-valued lanthanum and cerium elements. These two products are frequently stockpiled at the mine because prices are very low. The illegal miners seek the higher valued REs—especially the magnet materials neodymium, praseodymium, dysprosium, and terbium—and simply dump onto the market the low-value elements regardless of price. This behavior further erodes the profitability of the legal northern firms.

### The efficiency of export quotas and smuggling

Illegal RE products also escaped through the border of China and undermined the effectiveness of export quotas. China's

<sup>8</sup> Packey and Kingsnorth (2016) point out that the trade of illegal products uses cash and does not involve any invoice. The illegal products become legal gradually from the small processor to larger processors with lenience.

<sup>9</sup> Although it is hard to verify that this speculation is universal for the entire industry, two pieces of information from the website of the Commission for Discipline Inspection of the Central Committee of the CPC (CCDI) and the Ministry of Supervision of the People's Republic of China provide limited evidence. Both cases relate to the city of Ganzhou, Jiangxi Province, which is known for its rich and special RE ores—ionic clays. First, in 2014, the secretary of the County Committee of An'yuan (it belongs to the city of Ganzhou), Guanghua Kuang, was sentenced to 17 years in prison as he abused his right and allowed illegal RE mining by his relatives since 2011. Moreover, about 20 officials were involved in illegal RE mining and bribery and purchased 104 mining sites in An'yuan (CCDI, 2014). Second, in 2017, the former Vice President of the Inner Mongolia autonomous region government, Yiyang Pan, was sentenced to 20 years in prison as he accepted and extorted bribes in exchange for mining permits from 1999 to 2014. Before he was promoted and moved to Inner Mongolia in 2010, he was a member of the Standing Committee of the Jiangxi Provincial Committee of the CPC and the Secretary of Municipal Party Committee of Ganzhou (the top leader of Ganzhou). The website shows that from 2000 to 2013, Vice President Pan gave bribes to the former Secretary of the Secretariat of the CPC Central Committee and Chief of the General Office of the Communist Party, Jihua Ling (CCDI 2017). The corruption in the mining industry and, generally, the institutional problems in China are worth additional investigation but exceed the scope of this study.

illegal RE exports were significant. For example, the export quota in 2008 was 57,000 t of RE gross products. However, Europe, USA, and Japan imported about 71,000 t of RE products (metals, compounds, oxides, and so on) from China, which is 14,000 t higher than the maximum legal export (Schüler 2011). Table 2 shows, except for 2009, the reported import of RE products from China was greater than the reported Chinese export for the same basket of products for the period 2009–2013.

Chinese exporters and foreign importers reacted to the price increases of 2010 and 2011, discussed below. Illegal exports followed higher prices—even as, in 2011, legal exports (China’s reported export) decreased due to weaker global demand as the high price drove substitution and encouraged mining outside of China. In 2012 and 2013, due to both the lower prices and the policies, we will see in the subsections below illegal exports apparently decreased (Wang 2012).

### Reduction in export and production quotas and skyrocketing price

As we can see from Fig. 7, despite China having a cluster of policies around 2005 and 2006, illegal production kept stable at about 30% of production. Against this backdrop, in 2010, China implemented a stricter RE policy, especially the export quota and the MIIT production quota. The production quota from MIIT decreased from 119,500 metric tons of RE oxide to 89,200 or about 25% (Fig. 5). The export quota decreased from 48,155 metric tons to 30,258 metric tons, or 37% (Fig. 4). By making export permits more difficult to obtain, China was able to influence industrial and environmental standards and reward those firms who met the standards (Yang 2015, p261). As a result, RE prices increased greatly as we see in Fig. 1. Some argue that the price increase was a reaction to the territorial dispute between China and Japan in September 2010 (Morrison and Tang 2012; Kiggins 2015)—that is, China took advantage of its dominance of RE supply to Japan and suspended RE export during the sudden

political conflict. However, we agree with Wübbecke (2013) that we should view the tightened Chinese RE policies in a broader framework as the MLR quota slightly increased from 2009 to 2011 and the decreasing of MIIT quota was announced in March, prior to the territorial dispute. For export policy, MOFCOM announced the second round of quota in July 2010, which happened before the dispute as well. We would argue to view the price determinant mechanism in a more systematic way. The focus on the influence of the territorial incident masks the underlying movement of market structure and misreads the policy makers’ and relevant firms’ understanding of long-term trends. Even though the magnitude of the change in quotas was surprisingly large, we can see a tendency of stricter policies when we look back at the 2000s. For example, the trend of decreasing export quotas started as early as 2006. From a different angle, we can infer that the targets of the Chinese central government were not fully achieved by the earlier policies.

In 2010, China was producing 97% of the world RE supply (Fig. 2). Given the long lead times for development of new mines, the rest of the world could not start to produce or expand capacity immediately in response to the surprising supply shortage. Because of the inelastic supply and the market panic, the prices began to climb in the middle of 2010 and reached the unprecedented level in the middle of 2011—a full year after the dispute with Japan. Most of the prices of RE metals and oxides experienced a thousand-percent increase (Fig. 1). This phenomenon was apparently triggered by the drop of the quota directly but was also impacted by the tightened policies in the past four to five years as discussed in the “Industrial order, more restrictions on foreign investment, and export taxes” section.

From 2011, other countries with considerable RE resources, such as the USA, Australia, and Russia began to increase or restart their production. The production of the rest of the world increased from 3380 t in 2010 to 21,200 t in 2016. Accordingly, China’s market share decreased to 83% (Fig. 2).

**Table 2** China’s rare-earth products export data and the ROW import data. Source: Roskill (2015)

	Quantity (t)					Value (US\$000)				
	2009	2010	2011	2012	2013	2009	2010	2011	2012	2013
Total reported import from China	42,752	56,488	40,193	24,602	30,391	333,196	1,008,934	3,557,691	1,254,775	642,206
China’s total reported export	43,923	39,816	16,859	16,266	22,500	309,629	938,863	2,665,615	906,682	568,720
Import–export	–1171	16,672	23,334	8336	7891	23,568	70,071	892,076	348,093	73,486
Quota	50,145	30,258	30,246	34,638	30,999					

The data above are not strictly comparable from year to year as the units used to quantify quantity vary over time. The purpose is to indicate general trends only

By 2016, prices had returned essentially to the level of 2010. China had rescinded its export taxes and quotas per the World Trade Organization (WTO) settlement, described below.

### WTO dispute

China's restriction on production and international trade on RE products, especially the latter, triggered protests of improper conduct mainly from the USA, Japan, and the European Union, whose high-tech industries were dependent on imported rare earths. These countries sued China at the WTO and argued that, first, China's export taxes on ores and primary RE products, as well as on tungsten and molybdenum, were not listed in the Protocol on the Accession of the People's Republic of China (the Protocol) and thus should be removed. Second, China's substantial restriction of the export of RE products violated the terms of WTO and the Protocol. Third, China's regulation and allocation of the export permit did not follow the promises in the Protocol. Meanwhile, China claimed that its export policies were reasonable according to the exceptions in Article XX and Article XI of the GATT 1994 since the purpose was to protect nonrenewable resources, the environment, and human health. China lost the WTO RE dispute case as the export restrictions did not meet the requirements of the exceptions in the Protocol. China canceled its export quota and export tax on RE products in 2015. Thereafter, firms need not get approval for exports and can acquire licenses based on trading contracts (Qian 2014; MOFCOM 2015; MoF 2015).

China could have tried to reserve the right to place restrictions on the export of natural resources through multilateral WTO negotiations during the 1990s. However, the motivation of spurring export through domestic (value-added) manufacturing overwhelmed the interest of protecting resources and environment even though the government had realized the importance and problems related to the RE ionic clays as early as 1991—suggesting some delay in China's policy implementation. Moreover, Chinese RE reserves are located in more remote and less-developed regions where local governments need foreign exchange to relieve fiscal stress (Yang 2015, p122). Therefore, as noted earlier, there was conflict between the goals of economic development and resource and environmental considerations.

### “Opinions” from the central government: declaration of objectives for structural change

Up to now, the paper has described the impacts of the export quotas, illegal mining, the spike in prices, and the WTO dispute. This section focuses on several additional policies adopted during this time period, 2010–2015. In May 2011, the State Council of China released a vital document that provides general ideas of the planning for the RE industry

named “Several Opinions of the State Council on Promoting the Sustainable and Healthy Development of the Rare Earth Industry” (State-Council 2011a). Another document, “Situation and Policy of China's Rare Earth Industry,” released by the State Council Information Office offered similar opinions (SCIO 2012).

The documents state that the Chinese central government attempts to, first, change the structure of industry by controlling the capacities of mining and separation and encouraging the innovation of new technologies in the downstream industry; second, to protect the environment and sustainability of resources by employing higher environmental standards, establishing industrial order, and imposing more efficient resource and environmental taxes; third, to weed out backward production technology that is not qualified according to the emission standards, and to promote the technical transformation of the mining industry; fourth, to complete the laws and regulations along the supply chain for a unified, normative, and efficient RE regulation system; fifth, to accelerate the process of merging and creating an industrial structure led by dominant firms, including the goal that the industrial concentration of the largest three southern ionic clay RE firms should be 80%; sixth, to coordinate the RE industry with the local economies and the interests between different entities (central government and local government, state-owned enterprises and private firms, local government and local firms, state-owned enterprise owned by the central government and local governments); seventh, to coordinate the relevant national ministries and departments in terms of planning and policy implementation; and last, to increase the qualification requirements for RE exporting firms and crack down on illegal exports.

### Environmental regulations and treatment of illegal activities

Starting from this stage, China began to employ environmental policies and industrial standards for RE production emissions. Deteriorating environmental quality posed serious threats to public health and social stability. For the RE industry, according to official data in 2012, the city of Ganzhou, Guangxi province, needed US\$ 5.8 billion solely for land reclamation not to mention health costs and other environmental pollution. By contrast, the average annual profit from 2002 to 2012 of Ganzhou's RE industry was only about 0.3 billion US dollar. To help treat environmental issues, the central government gave fiscal support to local governments (MLR 2015c). Wübbecke (2013) provides another example of pollution in Inner Mongolia, northern China.

In 2011, the first industrial standards for air and water pollution of RE industry were introduced (MEP and AQSIQ 2011), followed by a specific inspection process associated with the environmental impact analysis (MEP 2011a). In

2013, standards became more detailed by specifying air pollutants (MEP and AQSIQ 2013). The industry entry standards prevented small and outdated technology from proposal approval. RE-specific environmental standards marked the latest focus of the new administration. As China achieved more economic progress, environmental issues became the top topic on policymakers' agenda.

Environmental damages are highly related to illegal mining. Simultaneously, the government used environmental requirements to restrict illegal RE production. The crackdown on the illegal and black market activities mainly led by MLR and MIIT started in 2010 and was aimed at investigating and punishing illegal mining, processing, and trading. A crackdown campaign ending in April 2017, led by the RE office and with the participation of other related ministries, included investigations in 23 provinces and inspections of 415 firms in the RE supply chain. Figure 14 shows that there were such administrative activities in almost every year, which implies that the problems of illegal production are complicated to deal with for the central government (MLR 2010b; MIIT et al. 2011a, b; MIIT 2012c; MIIT et al. 2013a; MIIT et al. 2014, MIIT et al. 2016, MIIT 2017c).

### Resource tax reform

In 2011, the RE resource tax increased from 0.4–3 yuan/t to 60 yuan/t for light RE ore (for example, bastnasite and monazite minerals) and 30 yuan/t for middle-heavy RE ore (for example, xenotime and ionic clay minerals). The resource tax reform intended to capture the scarcity of the RE resources and the externality caused by mining and processing. Starting in 2015, the resource tax for RE ore changed from quantity based to value based. The tax for three provinces—Inner Mongolia, Sichuan, and Shangdong—are 11.5%, 9.5%, and 7.5% of the value of sales of RE concentrate equivalent. The rate for middle-heavy RE ore is 27% of sales. The resource tax caused

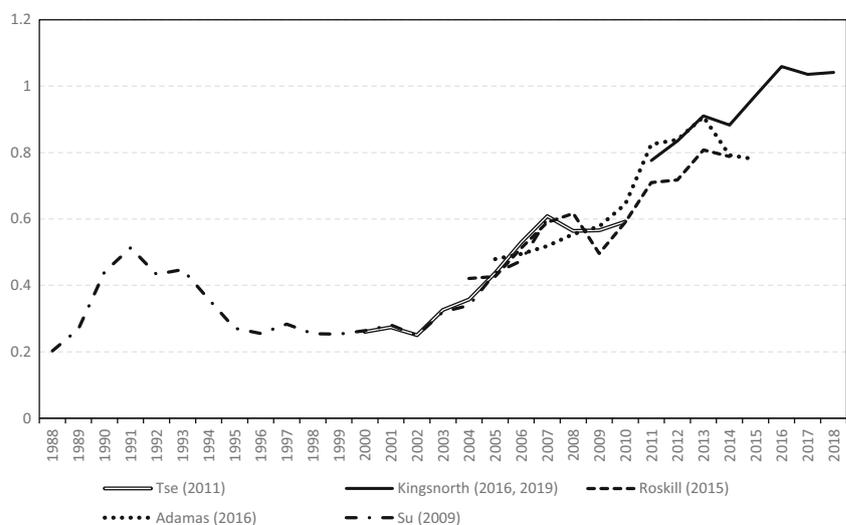
two problems. First, illegal mining that did not pay the tax drove down prices and thus reduced the profitability of legal firms. Without treating illegal production effectively, the resource tax made it harder for the legal firms to survive (Chen 2015). Therefore, the resource tax has to work together with policies that reduce illegal activities. Second, local governments, on one hand, collected extra fees beyond the resource tax that put the legal firms into a worse financial situation, while on the other hand failing to use the RE fees to deal with RE problems effectively. With the tax reform in 2015, the State Council required local governments to cancel resource compensation fees, price adjustment funds, and all other fees (State-Council 1994, 2011b; MoF and SAT 2015; MoF and NDRC 2015; Fu et al. 2017).

### The development of the downstream sector

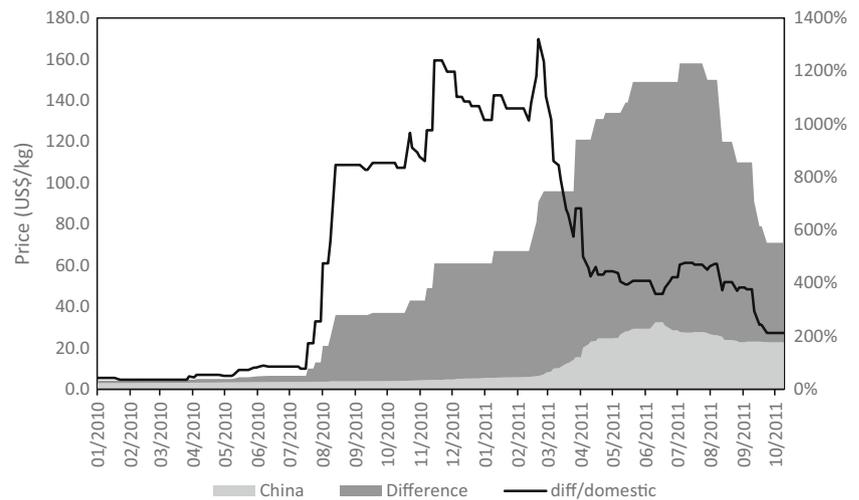
China's policies actively encouraged the domestic downstream industry. The focus of the RE supply chain moved to downstream sectors along with the development of the entire mineral industry and China's economy. Tse (2011) shows that China's consumption of RE mineral increased from 19,000 t in 2000 to 77,000 t in 2010, an annual growth rate of 15%. Roskill (2015) has a similar estimation that, from 2004 to 2014, China's consumption increased by 7.5% annually from 40,000 to 82,750 t and the consumption by downstream sectors of the rest of the world decreased by 3.8% annually. During this period, China's share of world consumption rose from 43 to 70%. Adamas (2016) data verify the demand of RE products in Roskill (2015) and show that China's production of RE end-use products increased from 56,984 t in 2005 to 81,858 t in 2015. By 2015, Chinese domestic consumption of rare earths grew to 80% or more of domestic production (Fig. 8).

The RE price was a key factor driving the size of the Chinese downstream RE sectors. During the period of

**Fig. 8** China's demand for rare-earth products relative to its rare-earth production. Data sources of China's demand of RE products and the production of RE end uses are shown in the figure. For RE production, we use the USGS data. Starting in 2014, USGS uses the Chinese official quota as the actual production, therefore the ratio may exceed one



**Fig. 9** Difference between the Chinese domestic rare-earth prices and the export prices (cerium). Data source: Argus Media (2016). The light gray area (the bottom part) represents China's domestic RE price. The dark area represents the difference. The Total is the international RE price. The line (right axis) shows the difference in export prices as a percent of the Chinese domestic price. For example, the export price in September 2010 is about 850% higher than the domestic price



export quotas and taxes, domestic Chinese prices were significantly lower than Chinese export prices available to customers in the rest of the world. Taking the price of cerium as an example, the dark gray area in Fig. 9 shows the absolute difference between the Chinese domestic price for cerium and export price. The line shows the relative difference. The price difference worked as an incentive for the expansion of the Chinese RE end-use production firms, as shown in Fig. 10.

### 2016–2018: post-WTO dispute, consolidation of RE industry, systematic regulations

The cancellation of the export quota accelerated the arrival of a new period of Chinese RE policy. We should understand this in broader terms, that is, the development of the entire Chinese mineral industry. Yang (2015) describes two other trade disputes that China lost: on export quotas for coke in 2004 and on nine mineral raw materials in 2012. Losing these international trade disputes—as well as the WTO suit on rare earths, tungsten, and molybdenum—encouraged China to use domestic policy tools, rather than restrictions on international trade, to deal with the domestic RE market directly. From 2016 onward, China continued to place priority on earlier objectives—that is, establishing industrial order, treating environmental problems, and encouraging downstream use of rare earths. For example, the Environmental Protection Tax Law was passed by the National People's Congress of China and became effective in 2018. The law, first, forces RE firms to internalize their environmental costs and, second, can be used to combat illegal production. Moreover, the central government is promoting RE Metals Regulation (MIIT 2016c). The overuse of administrative policies has delayed the marketization (or competitiveness) of the industry. The

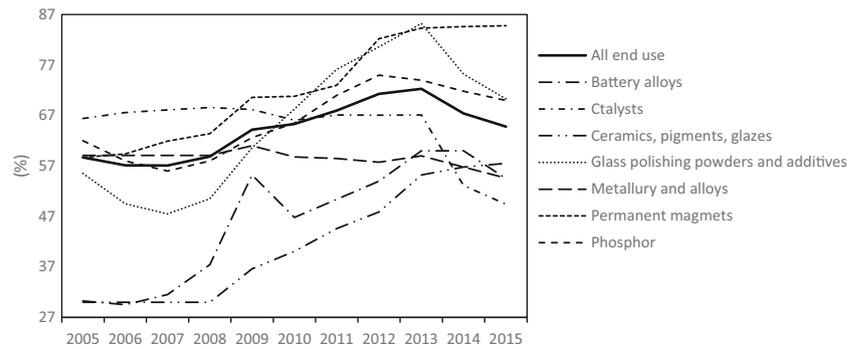
profitability of RE firms, especially the state-owned firms, depends heavily on government policies rather than market activities such as innovation. In addition, abundant administrative policies create room for rent seeking and corruption (Yang 2015, p 25).

### The six rare-earth groups

The promotion of mergers and acquisitions started from 2002 (Wübbecke 2013). Since then, several calls were made from the central government. However, they did not bring substantive progress in industry consolidation until recent years (MFTEC et al. 2002; State Council 2005; MLR et al. 2007; State-Council 2010, 2011a; MIIT 2013). The reasons behind the difficulty of consolidation are similar to those of illegal production, namely, conflicts of interest. Local governments, especially in southern China, are reluctant to hand a key industry over to a state-owned group that is not located in their province (Yang 2015, p105). With the national calls for consolidation and a failed proposal in 2002, the new consolidation plan was officially announced in 2015, after a decade, in the MLR production quota document (MLR 2015a). A 2017 MIIT document finalized the names (and the constitutions) of the groups, as shown in Table 3. The central government through the State-owned Assets Supervision and Administration Commission controls the first three groups. The dominant stockholders of the remaining three groups are either provincial or city governments. Each of the groups covers various parts of the RE supply chain, but principally the upstream and midstream sectors. The six RE groups took nearly all the mining and separation quotas (MIIT 2017a and 2017b).<sup>10</sup> This marks a new era in China's RE policy. Meanwhile,

<sup>10</sup> A reviewer noted that the six RE groups have held 77 of 78 RE mining licenses since 2017.

**Fig. 10** China's share of rare-earth end-use products supply. Data source: Adamas (2016)



strategically speaking, with the six state-owned (either owned by central government or local governments) RE groups, the central government may be able to control the entire industry more effectively. Figure 11 roughly shows the geographic distribution of the RE firms that form the entire industrial chain.

The policies focused on the production of primary RE products making the mining and separation firms profitable while putting significant pressures on the firms who produce end-use products (Wu and Luo 2014). The upstream sector has better financial performance as there are fewer firms due to the limitation of permits and quotas, while the downstream sector is more competitive (Yang 2015, pp. 162–169). Such circumstances created incentive for horizontal mergers of RE firms. The North Chinese RE group, which controls the entire supply chain in the region, is an example.

Previous researchers claim that China has a monopoly of the RE industry, especially between 2005 and 2011 when China produced 97% of the RE products. It is true that China as a nation owns a large portion of the RE reserves and dominated the upstream and, recently, downstream production of RE products. There appears to be a contradiction between the theoretic monopoly behavior and the facts of the lower prices and high quantity in

the Chinese RE industry and the efforts of the Chinese central government to crack down on illegal production and consolidate the industry. Even after the current consolidation of the RE industry, there are six groups to compete with each other. In addition, beneath the surface of the state-owned RE groups, there are hundreds of RE firms that are run and owned by private entities (Yang 2015, p105). The competition inside of China explains why, even when legal production is restricted, RE prices are low.

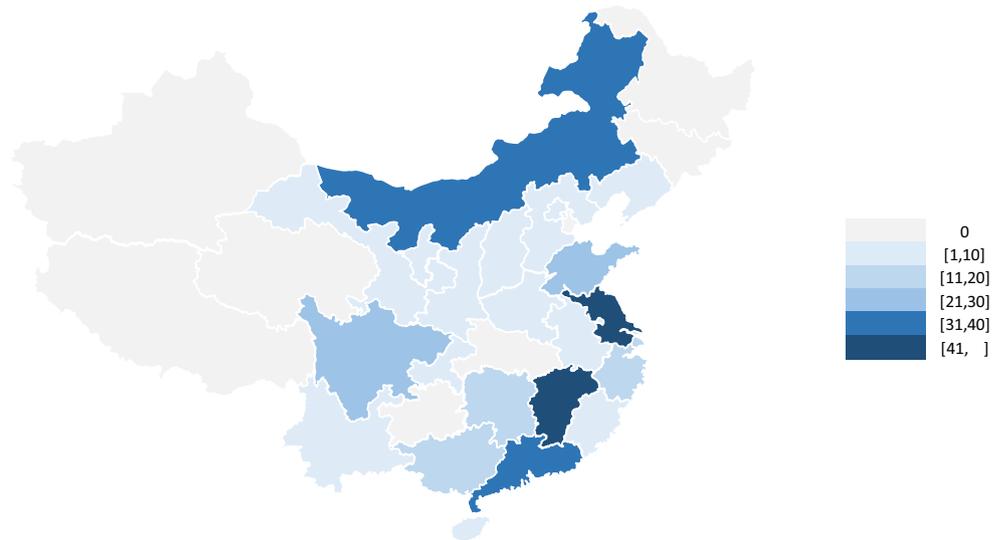
### Rare-earth industrial plan

In September 2016, China released the Development Plan of Rare Earth Industry (2016–2020) (MIIT 2016c). In Table 4, we pull from the document summary some of the key objectives that the Chinese central government plans to achieve. From the Economic Indicators and the Application Industry Development Indicators, we infer that China will keep carrying out policies that stimulate the development and innovation in the downstream sectors in order to increase the added value of the entire RE supply chain. It is not easy to reach the listed goal for industrial value added as after 2013 China's share of most end uses decreased. Success in meeting this goal largely

**Table 3** The 2017 MIIT Production quota. Source: MIIT (2017a, 2017b)

	Headquarters	Concentrate		Separation	
		Assigned quota	Share (%)	Assigned quota	Share (%)
China Minmetals Corporation	Beijing	2260	2.15	5658	5.66
Aluminum Corporation of China Limited	Beijing	12,350	11.76	16,294	16.29
China Northern Rare Earth (Group) High-tech Limited	Inner Mongolia	59,500	56.67	50,084	50.08
Xiamen Tungsten Corporation	Fujian	1940	1.85	2663	2.66
China Southern Rare Earth Group	Jiangxi	26,750	25.48	15,197	15.20
Guangdong Rare Earth Industry Group	Guangdong	2200	2.10	10,104	10.10
Total		105,000	100.00	100,000	100.00

**Fig. 11** Spatial distribution of RE firms range from upstream to downstream in mainland China. Data source: 379 firms that need to be inspected, MIIT et al. (2016)



depends on end-use demand, efforts outside of China to secure the non-Chinese rare earths, and progress in research aimed at substituting away from rare earths.

The production quota in 2020 is set at 140,000 t. As in the past, implementation will be the key here. With increasing regulation and the formation of the six RE groups, the effectiveness of the production quota may increase.

The final production indicator promotes the product tracing system, which will assist the central government in overseeing the entire industry, but only if the compliance rate improves, per the Plan. The RE product tracing system focuses on concentrates and separated RE products. It intends to use the production and trading accounts and product labels to capture the full process. In 2017, the Ministry of Commerce, MIIT, the Ministry of Public

**Table 4** Rare-earth development indicators during the 13th five-year plan. Source: MIIT 2016c

Indicators	2015	2020	Accumulated change in 5 years
1. Economic indicators			
Industrial added-value annual growth (%)	12.5	16.5	–
Industrial profit rate (%)	5.8	12	6.2
Key R&D spending to main revenue (%)	3	5	2
2. Production indicators			
Capacity of smelting and separations (1000 t)	300	200	– 100
Output of smelting and separations (1000 t)	100	< 140	< 40
Light RE beneficiation recovery rate (%)	75	80	5
Ion-adsorbed RE beneficiation recovery rate (%)	75	85	10
Light RE smelting and separations recovery rate (%)	90	92	2
Ion-adsorbed RE smelting and separations recovery rate (%)	94	96	2
Percentage of firms satisfying information and industrial standards (%)	30	90	60
3. Environmental development indicators			
Reduce the emission of main contaminants (SO <sub>2</sub> , NH <sub>3</sub> -N, waste water, and so on)	–	–	20
Percentage of firms satisfying energy consumption standards (%)	40	90	50
4. Application industry development indicators			
Market share of advanced RE functional materials and devices (%)	25	50	25
Export proportion of primary raw materials (%)	57	30	– 27
Main RE functional materials (permanent magnets, catalysts, hydrogen storage material) have annual growth of 15%			

Safety, etc., promoted the establishment of the tracing system. They called for the creation of an experimental RE tracing system by using information sharing mechanisms such as special invoices, export declarations, enterprise managerial archives, and so on for RE products (State Council, 2016; MOFCOM et al. 2017).

For environmental considerations, MIIT (2016c) specifies that RE firms have to follow the Industrial Green Development Plan (MIIT 2016d), Rare Earth Industrial Standards (MIIT 2016e), Emission Standards of Pollutants from Rare Earths Industry (MEP and AQSIQ 2011), and, finally, the Norm of Energy Consumption per Unit Products of RE Metallurgical Enterprise (AQSIQ 2011). In addition, the Environmental Tax Law in 2018 may help to internalize pollution costs into firms' decision-making and provide foundations for law enforcement.

### National Mineral Resource Plan

China realized the strategic value of RE products in the early 1990s when it started to regulate the industry intensively. Recently, it wrote the word “strategic” in the 2016–2020 National Mineral Resource plan (MLR 2016b). The document encourages the establishment of a strategic mineral detection and warning mechanism for the RE industry, creating warning indicators, threshold values, and a comprehensive evaluation model. It also promotes demand and supply analysis of mineral products systematically and proposes to intensify the ability of risk warning in the case of international conflict. It aims to help government decision-making and lead the development of the RE industry. Further, the Mineral Resource Plan indicates that China intends to establish energy and resource bases as strategic areas that ensure national resource-supply safety. The Chinese government will support the development of those bases in capacity distribution, construction of infrastructure, resource allocation, project management, and industrial policies to promote resource exploitation at scale and the development of the industrial agglomeration. The six RE resource bases<sup>11</sup> will have more than 80% of the country's capacity.

### The future

With the deepening of China's economic transformation and recent policies, the Chinese central government has stronger control over the entire RE industry than in the past. However, strategically, risk still exists due to the potential conflict between China and its trading partners.

<sup>11</sup> They are Baotou, Inner Mongolia; Liangshan, Sichuan; Ganzhou, Jiangxi; Jianguhua, Hunan; Hezhou, Guangxi; and Southwest of Fujian.

As Wübbecke (2015) notes, strategic, as the Chinese put it, is more about economic activity than purely political considerations. As we see from the historical evolution of China's RE policy, China attempted to increase the added value of its RE resource endowments as with other non-renewable natural resources. To achieve the goal, China, on one hand, restricted the foreign involvement in the upstream to midstream sectors, while on the other hand not putting limits on the export of downstream products<sup>12</sup> (Wübbecke 2013).

For future research, we suggest two directions. First, how will China's policies encouraging the development of the RE industry downstream evolve? How will the industries that use RE-intensive products develop, especially in the renewable-energy sector such as motors in electric vehicles and wind turbines? With urbanization, China is simultaneously demanding more quality consumer goods, a better environment, and the infrastructure for higher standards of living. These demands will presumably drive the need for rare earth elements. We might wonder if China will carry out policies that not only promote the production of the end-use RE products, but also keep most of the products within China? One may find some clues from the following documents: “Made in China 2025,” “New Material Industry Development Plan,” and “Industry Green Development Plan (2016–2020)” (MIIT 2016c).

Second, how can we better understand the structure and internal working of the Chinese RE industry? As we noted, non-Chinese researchers often consider China a monopolist in the production of rare earths. This assumption is understandable for two reasons. The primary reason is that the Chinese government has at times attempted to control the export of RE products and thus people imagine that the government also controls all production. Moreover, the opaque nature of the RE industry means that limited information is available, especially in English, about the details of the Chinese industry. Reality is more complicated and worthy of additional study, especially in light of attempts to consolidate the Chinese RE industry into six large groups and, most recently, investments by Chinese companies in rare-earth deposits outside of China.

**Funding information** This work is supported in part by the Critical Materials Institute, an Energy Innovation Hub funded by the US Department of Energy, Office of Energy Efficiency and Renewable Energy, Advanced Manufacturing Office.

<sup>12</sup> An exception is that China put an export tax on NdFeB rapid-setting permanent magnet slices. However, we can consider NdFeB products as input for the further downstream sector such as wind turbines. China was trying to push its domestic RE industrial chain downstream.

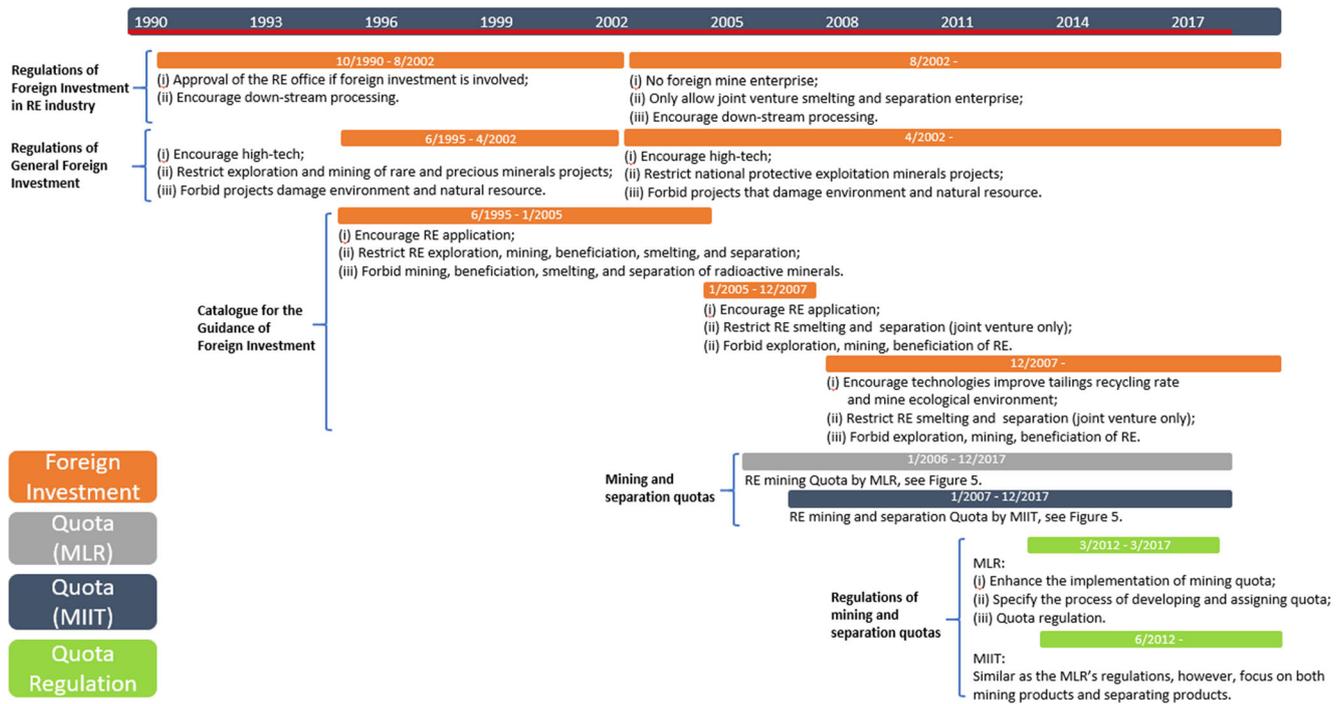
## Appendix

**Table 5** Chinese government and Chinese communist party institutions

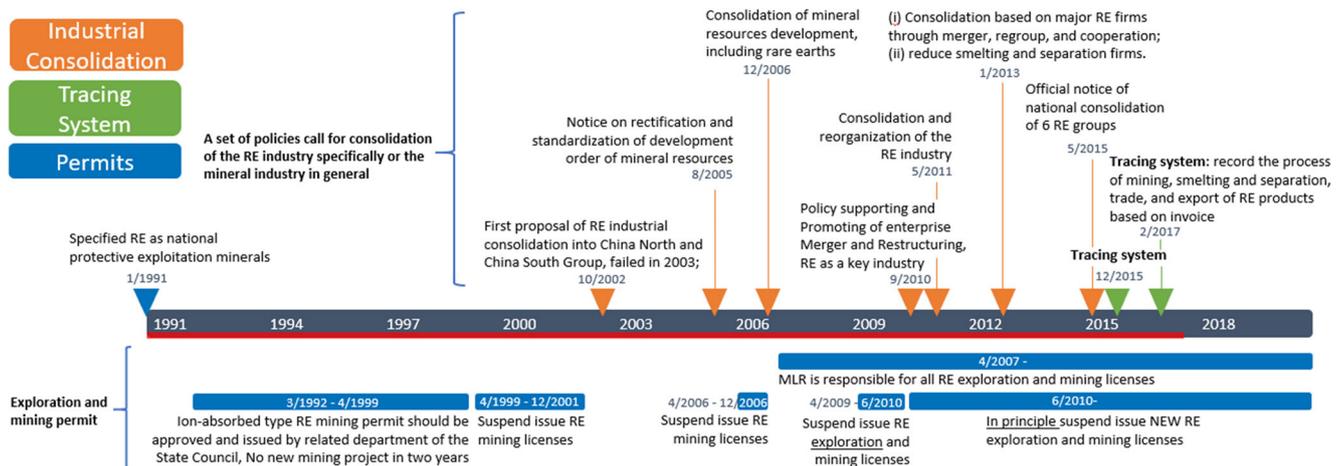
Institution	Abb.	Ministry (CN)	Abb. (CN)	Date
1 National Development and Reform Commission	NDRC	发展和改革委员会	发改委	2003–
State Development Planning Commission	SDPC	国家发展计划委员会	发计委	1998–2002
State Planning Commission	SPC	国家计划委员会	计委	1952–1997
2 Ministry of Land and Resource	MLR	国土资源部	国土部	1998–2018
Ministry of Natural Resource	MNR	自然资源部		2018–
3 Ministry of Industry and Information Technology	MIIT	工业和信息化部	工信部	2008–
4 Ministry of Commerce	MOFCOM	商务部	商务部	2003–
Ministry of Foreign Trade and Economic Cooperation	MFTEC	对外贸易经济合作部	经贸合作部	1993–2003
Ministry of Foreign Economic Relations and Trade	MFERT	对外经济贸易部	经贸部	1982–1993
5 Ministry of Science and Technology	MST	科学技术部	科技部	1998–
Commission of Science and Technology	CST	科学技术委员会	科技委	1977–1998
6 Ministry of Public Safety	MPS	公安部	公安部	1954–
7 Ministry of Environmental Protection	MEP	环境保护部	环保部	2008–
Environmental Protection Administration	EPA	环境保护总局	环保总局	1998–2008
8 General Administration of Customs	GAC	海关总署	海关总署	1980–
9 State Administration of Taxation	SAT	税务总局	税务总局	1993–
10 General Administration for Industry and Commerce	SAIC	工商行政管理总局	工商总局	2001–
11 State Administration of Work Safety	SAWS	安全生产监督管理总局	安监总局	2005–
12 General Administration of Quality Supervision, Inspection and Quarantine	AQSIQ	质量监督检验检疫总局	质检总局	2001–
13 The National People's Congress	NPC	全国人民代表大会	全国人大	
14 Ministry of Finance	MoF	财政部	财政部	1949–
15 State Council Information Office	SCIO	国务院新闻办公室		
16 the Commission for Discipline Inspection of the Central Committee of the CPC	CCDI	中共中央纪律检查委员会	中纪委	1993–
17 Ministry of Supervision	MoS	监察部		
18 Ministry of Human Resources and Social Security	MOHRSS	人力资源和社会保障部	人社部	2008–
19 Rare Earth Office	RE Office	稀土办公室	稀土办	1975–

**Table 6** The evolution of the rare earth office and NDRC

1952–1997	State Planning Commission	1975–1987	National RE Development and Application Leading Group
		1988–1994	The State Council Rare Earth Leading Group
1998–2002	State Development Planning Commission	1995–2002	The Planning Commission took charge
2003–	National Development and Reform Commission (NDRC)	2003–2007	RE Office (NDRC)
		2008–	RE Office (MIIT)



**Fig. 12** Industrial policy (I). Sources: RE office et al. (1990), SPC (2002), MOFCOM (2002), SPC and MFTEC (1995a, 1995b, 1997), NDRC and MOFCOM (2002, 2004, 2007, 2011, 2015), MIIT (2009–2011, 2012a, 2016a, 2016b, 2017a, 2017b), MLR (2006, 2007a, 2008, 2009, 2010a, 2011, 2012a, 2013, 2014, 2015a, 2016a, 2017), MLR (2012b), MIIT (2012b)



**Fig. 13** Industrial policy (II). Sources: MFTEC, et al. 2002, State-Council (2005), MLR et al. (2007), State-Council (2010, 2011a), MIIT et al. (2013b), State- Council (2016a), MOFCOM et al. (2017), State-Council (1991), MLR (1999, 2001, 2006, 2007b, 2009,2010a, 2011a, 2011b, 2013, 2014,2015a, 2015b). Rare Earth Office (1992)

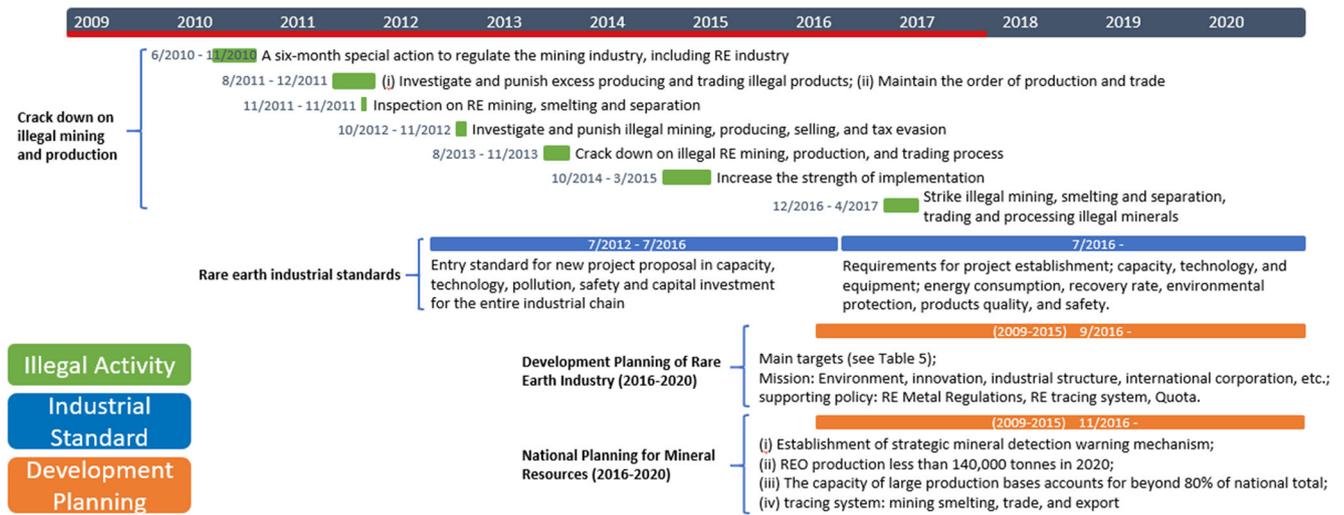


Fig. 14 Industrial policy (III). Sources: MLR (2010b, 2016b), MIIT et al. (2011a), MIIT et al. (2011b), MIIT et al. (2013a), MIIT et al. (2014), MIIT et al. (2016), MIIT (2012c, 2012d, 2016c, 2016e)

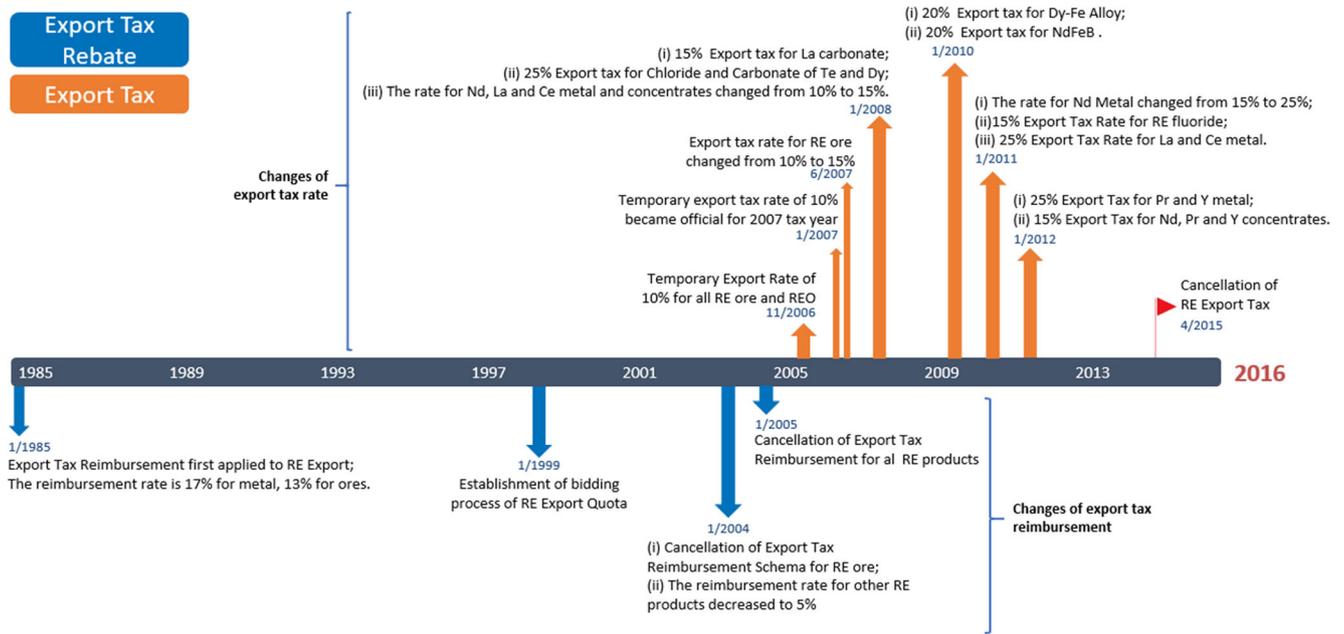
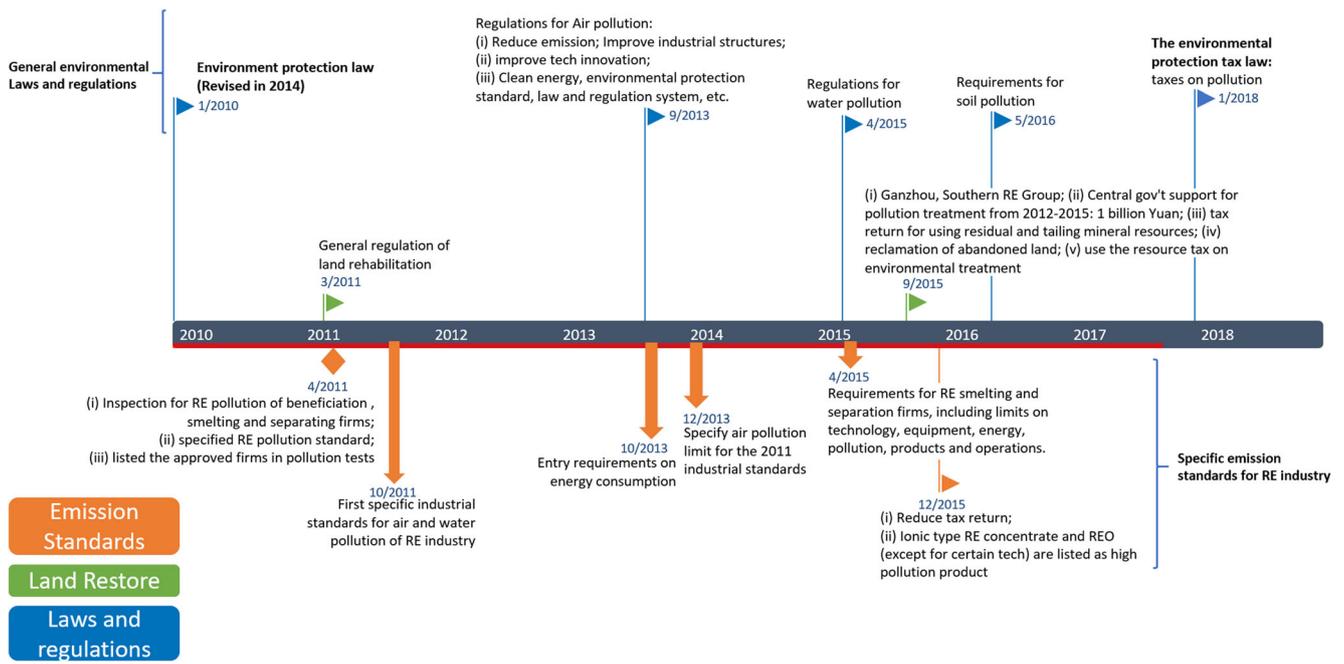
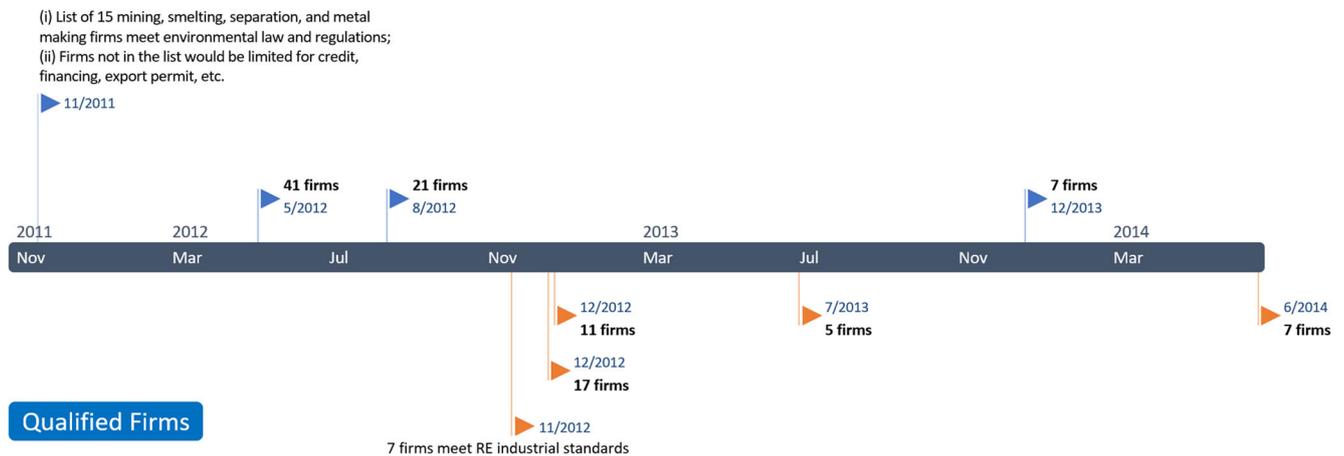


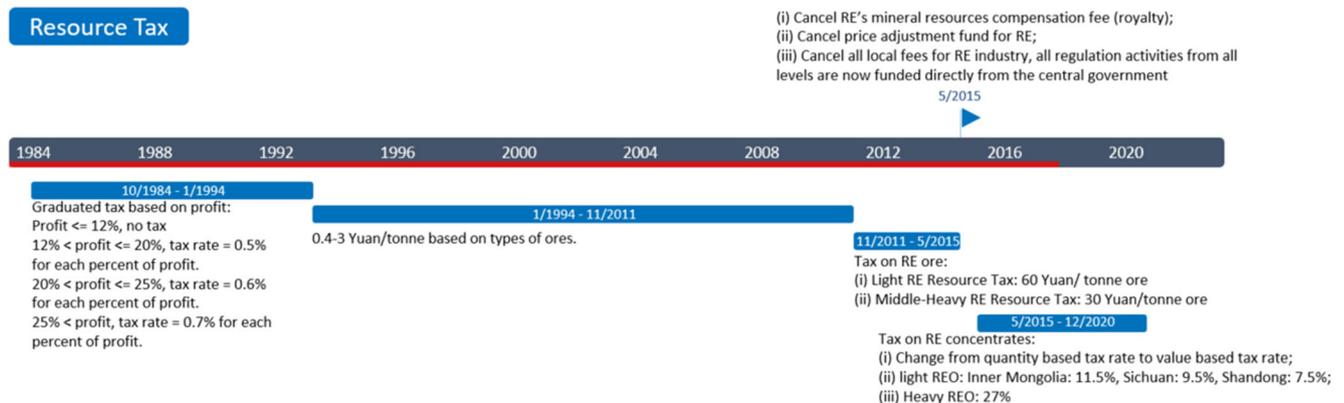
Fig. 15 Export policy. Sources: State Council (1985), MoF and SAT (2003, 2005), MoF (2006, 2007a, 2007b, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015)



**Fig. 16** Environmental policy (I). Sources: MEP and AQSIQ (2013), MEP (2011a), AQSIQ (2011), NDRC, et al. (2015), MEP (2015), State-Council 2011c, 2013, 2015, 2016b), MLR (2015c), NPC (2010, 2016)



**Fig. 17** Environmental policy (II). Sources: MEP (2011b, 2012a, 2012b, 2013), MIIT (2012e, 2012f, 2012g, 2013, 2014)



**Fig. 18** Resource tax. Sources: State-Council (1984, 1994, 2011b), MoF and SAT (2015), MoF and NDRC (2015)

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