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An adjustment in regulation policies and its effects on market supply: Game analysis for China's rare earths

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ABSTRACT

In this context, this paper analyses the scenario in which China abolishes export restrictions and the resulting effects on firms at home and abroad by building a static game-theoretic model. We also establish a dynamic game-theoretic model with complete information to simulate another scenario that China enhances resource tax and levies an environmental tax and to evaluate its effects on firms in China and abroad in different tax rates. The results show that when abolishing rare earths export restrictions, China's rare earths production and export will increase; while rare earths production, domestic supply and price in foreign country will decrease. Moreover, if the Chinese government enhances resource taxes and levies an environmental tax, the production, domestic supply, and exports of rare earths will decrease in China, whereas the opposite effects will exist in other countries. Furthermore, a reasonable rate for the resource and environmental tax should be identified because it is the key factor affecting the market supply in China and abroad. Finally, several policy implications for the Chinese and other governments are proposed.

1. Introduction

Rare earths are important strategic mineral resources that are widely used in various areas of national economic development. Rare earths also are indispensable elements in modern industry, with uses in new energy, new materials, energy conservation, environmental protection, aerospace, and electronic information industries because of their unique physical and chemical properties (McLellan et al., 2013). However, with approximately 23% of the world's total rare earth reserves, China has been satisfying more than 90% of the world's demand for decades (MOC, 2014a) (see Table 1). As the largest exporter of rare earths in the world, China's rare earths are largely exported to Japan, the United States and the European Union (Wübbeke, 2013).

Great mining value and the unsustainable policy orientation that China merely treated rare earths as a general resource and a tool to earn exchanges by the export tax rebate in early China result in the over-exploitation of China's rare earths and environmental pollution. To solve these problems and further promote the sustainable and healthy development of the rare earths industry, the Chinese government has implemented a series of policies, including total control of mining quantities, mandatory production plans, export quota, export tariff, resource taxes and so on. Some of these policies on rare earths are implemented by administrative means, such as the first three ones listed above. The implementation of these policies, to a certain extent, alleviates pressure on domestic resources and the environment. However, declining rare earths exports have not met the growing demand of other countries for rare earths (see Fig. 1). Therefore, the European Union, Japan and the United States teamed up to bring a joint case in March 2012 to the WTO over China's measures on rare earths export and claimed that the export quota and export tariff had limited other countries' access to the minerals, giving China a competitive advantage and hurt other producers and consumers (MOC, 2014b). In the view of the European Union, Japan and the United States, export quota and export tariff on rare earths have not only distorted domestic and world markets in rare earths, but also impacted entire manufacturing chains and had broad implications for competition and trade in a wide variety of products by giving China a price advantage and a disadvantage for other countries. In addtion, they pointed out that export quota and export tariff on rare earths also have provided a substantial competitive advantage to Chinese users that produce downstream products over foreign competitors (WTO, 2014). In response, China referred to the export controls as a way to achieve sustainable development (Wübbeke, 2013). However, the WTO finally ruled,

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Table 1
Production structure of the world's rare earths: 2005–2014.

Year	Rare earths production (tons)					Production of China (%)
	China	US	India	Russia	World total	
2005	98000	0	2700	2000	105000	93.33
2006	120000	0	2700	NA	123000	97.56
2007	120000	0	2700	NA	124000	96.77
2008	120000	0	2700	NA	124000	96.77
2009	120000	0	2700	NA	124000	96.77
2010	130000	0	2700	NA	133000	97.74
2011	130000	0	2800	NA	133000	97.74
2012	95000	7000	2800	NA	110000	86.36
2013	100000	4000	2900	2400	110000	90.91
2014	95000	7000	3000	2500	110000	86.36

Data source: U.S. Geological Survey (2006–2015).

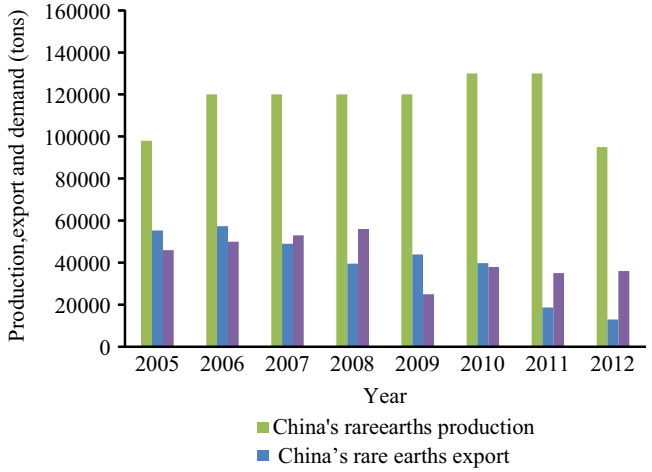

Fig.1. China's rare earths production, export and the demand of the rest of the world. Data source: Roskill (2012).

"China's measures are inconsistent with China's obligations under the GATT 1994 and the Accession Protocol" (WTO, 2014).

After losing the case, it was only a matter of time until China ended export restrictions, including export quota and export tariff. The Ministry of Commerce (MOC) reported that China abolished rare earths export quota on December 31, 2014. Additionally, on January 21, 2015, the MOC announced that China's rare earths export tariff would be abolished on May 2, 2015 (Xinhua, 2015). It is also worth mentioning that the export quota and export tariff have already triggered a large amount of smuggling and around 800 t of smuggled material could be tracked down in 2011 and 2012 (State Council, 2012; Xinhua, 2012). So the abolishment of export quota and export tariff may reduce the smuggling to some extent. After abolishing the rare earths export quota and export tariff, the control of rare earths exports of China will be greatly weakened. Therefore, Chinese rare earths regulation policies might prioritize domestic exploitation and production in the future (Wang, 2011). Adjustments in China's rare earths regulation policies will greatly influence firms in China and other countries. Moreover, as the world's largest producer, user, and exporter of rare earths, China's rare earths regulation policies adjustments have significant effects on rare earths supplies in the international market. Therefore, it is of great significance to analyze the adjustment in China's rare earths regulation policies and its effects on rare earths market supply in China and other countries and on firms' operations.

Rare earths are important strategic resources for economic development, the production and trade of which are not only integral to firms' operation and management but also involve government decisions. With the background of China losing the WTO lawsuit and strengthening the protection of resources and the environment, this study constructs the game-theoretic models including government tax policies and a firm's production and operation behaviors to analyze the rare earths market supply. To investigate the effects of an adjustment in regulation policies on rare earths in China, this paper builds a static game-theoretic model to examine the effects of abolishing the export restrictions and a dynamic game-theoretic model with complete information to evaluate the influences of enhancing resource taxes and levying an environmental tax.

Game-theoretic modeling is widely used in the areas of natural resources management, energy conservation, conflict resolution among resources utilization, economic development and environmental protection, and the interaction between a government's policy and enterprises' behavior choices. In the research of Carraro and Sgobbi (2008), Wei et al. (2010), Barough et al. (2012) and Lee (2012), game-theoretic modeling was applied to resolve conflicts between resource utilization and environmental protection, whereas Madani (2010) and Hui and Bao (2013) used game-theoretic modeling to explore the formulation of government policies and strategy selection of firms. In the context of changing global climate, a game-theoretic model was applied in green supply chain management by Zhao et al. (2012) and Hafezalkotob (2015). Clearly, game-theoretic modeling is a widely accepted approach to answering questions about resources conservation, environmental protection and the interactive relationship between government and firms.

China's important role in the rare earths market makes its regulation policy a topic of great interest. Hu (2012) noted that there was still a long way for China to modern market economy because Chinese government carried out regulation policies not only on the exploitation of rare earths resource but also on the production and export of rare earths products, which rarely happened in developed market economy countries. Moreover, it also pointed out that China's export quota and export tariff on rare earths did not comply with WTO rules (Hu, 2012). Meanwhile, Wübbeke (2013) indicated that the major driving motives of China's rare earths policies are domestic concerns for resources conservation and environmental protection. Zhang et al. (2015) conducted an empirical study to examine the influences of China's rare earths policies on other countries. Hayes-Labruto et al. (2013) debated the rare earths policy conflicts between China and the rest of the world (ROW) through a stakeholder lens. Zachmann (2010) and Tukker (2014) analyzed Chinese export regulation on rare earths and considered that it is noneffective for Chinese rare earths high-tech industries. Because of their wide use, rare earths are indispensable elements in modern industry; thus, increasing numbers of studies focus on rare earths demand, supply and prices. Golev et al. (2014) and Christmann (2014) provided overviews of existing and emerging rare earths supply chains outside of China and concluded that China's rare earths monopoly will be shaken by diversified supply in the near future. However, Massari and Ruberti (2013) indicated that there will be a shortage of rare earths in the future and that prices will rise sharply. Machacek and Fold (2014) focused on the efforts of Molycorp, Lynas, and Great Western Minerals group to build a Western primary REE supply chain in the view of global value chain (GVC) framework and concluded that the establishment of alternative REE supply chains was truly a challenging and delicate task. Wang et al. (2015) made a production forecast of China's rare earths based on the generalized Weng model and proposed some policy recommendations. Moreover, the environmental issues caused by rare earths exploitation and production have been widely realized. Habib and Wenzel (2014) studied the recycling of rare earths from the