Role of cross-application interdependence and competition in materials criticality identification and mitigation

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Abstract

Competing demand is argued to be one of the key forces leading to natural resource scarcity. Although the materials criticality discourse acknowledges importance of competition, the interactions of companies across applications have been neglected in the analysis. This paper grounds on the factor-market rivalry theory to examine the presence of cross-application interdependence and competition among companies manufacturing different products. The findings indicate that companies across industrial sectors are interconnected through their resource decisions and actions that affect common resource market. Competitive conditions at resource (and product) market impose limitations for feasibility of materials criticality mitigation actions.

Keywords: critical materials, competition, interdependence

Introduction

Availability of and access to natural resources such as minerals are considered as indispensable pillars for prosperity of nations and industrial competitiveness. It is possible to link various military conflicts and land explorations with a necessity to enlarge and secure resource base. Buijs and Sievers (2012) point out that resource management at the international arena is tightly linked to political regimes. Throughout the last 140 years resource management (mineral regime) experienced significant transformations: from imperialism and colonialism to cold war, from liberalism to current tendency toward resource nationalism (Buijs and Sievers 2012). However, the dispute over access to resources is no longer only concern of national importance. Nowadays, companies operate globally and source resources from multiple locations. Morley and Eatherley (2008) report raising concerns of companies about availability and affordability of resources, stemming from increasing control of these resources by fewer organisations and protectionism in favouring

domestic industries etc. The disruption of supply of rare earth elements in 2010 due to export quotas reduction by China is a good example of vulnerability of minerals supply chains to governmental interventions.

Rare earth elements along with several other materials are considered as critical because they are subject to high probability of supply disruptions and high economic impact of such disruptions (Erdmann and Graedel 2011; Graedel and Reck 2015). Materials criticality concept refers to a complex multidisciplinary phenomenon, and plethora of factors and assessment methods have been suggested for its analysis (Achzet and Helbig 2013; Helbig et al. 2016). However, as the concept was initially introduced in the political circles, the criticality analysis is mainly conducted within a scope of an industrial system (be it a country or a region), giving little attention towards the company dimension: heterogeneity and complex interactions of companies. This paper aims to address this gap by focusing on examination of inter-sectoral company relations.

In the materials criticality discourse, inter-sectoral relations are often considered in terms of competition. Graedel et al. (2012) point out intensity of competition as a crucial factor for materials criticality, but researches do not include it as an indicator in the proposed criticality assessment methodology. Some studies consider the presence of alternative applications of a material as an indicator for competing demand (e.g. Nieto et al., 2013; U.S. Department of Energy, 2010). However, these studies do not examine the nature of inter-sectoral relations of companies, if the competition is present and how it affects identification and mitigation of materials criticality.

From the organisational perspective, competition has been primarily examined for product market positions, and resources have been regarded as means for gaining competitive advantage, rather than as objectives for competition. Recently proposed factor-market rivalry (FMR) theory focuses on investigation of competition over resource positions and postulates that companies do not necessarily have to produce the same products to compete for resources (Markman et al. 2009). FMR is employed in this paper as a theoretical lens to examine inter-sectoral interactions of companies and their influence on materials criticality.

In particular, the following research questions are posed:

- RQ1: How do companies across different industrial sectors interact to obtain critical materials?
- RQ2: How do inter-sectoral interactions influence identification and mitigation of materials criticality?

The paper examines the case of rare earth elements (REE) crisis due to export quotas reduction by China in 2010. The research questions are empirically investigated through a qualitative case study research based on secondary data analysis of three manufacturers – Vestas (wind turbine), Continental (electric motors) and Siemens (wind turbine and electric motors). The paper brings attention to heterogeneity of companies and complexity of their interrelations inbuilt into the industrial system, arguing that these dimensions should not be missed in the materials criticality analysis.

Factor-market rivalry as a theoretical lens

The competitive dynamics research primary examines competition over product market positions between companies within the same industry or within a strategic group with similar strategic attributes (Markman et al. 2009; Chen and Miller 2012), where resources

are considered for identification and/or analysis of competitors (c.f. Chen, 1996; Peteraf and Bergen, 2003). However, Markman et al (2009) highlight that rivalry occurs wherever two firms overlap and can happen throughout the entire supply chain with multiple dissimilar firms. In particular, the researchers conceptualize factor market rivalry (FMR) and define it as "competition over resource positions" (Markman et al. 2009, 423). Barney (1986) define strategic factor market as "a market where the resources necessary to implement a strategy are acquired". The terms "factors" and "resources" are usually used interchangeably with the same meaning in the literature.

FMR states that companies may compete for common resources even when they target different product markets. Grounding on Chen (1996)'s framework of competitor analysis, Markman et al (2009) describes the matrix of resource-and product-market overlap (see figure 1). However, it should be noted that product and factor markets are not independent. Markman et al. (2009) indicate that factor market for one company can be product market for another and competition at the factor markets can migrate to the product market and vice versa. Effective product market competition requires strong resource position (Markman et al., 2009), which is also in line with resource based view (Barney 1991) and resource-advantage theory (Hunt 1995).

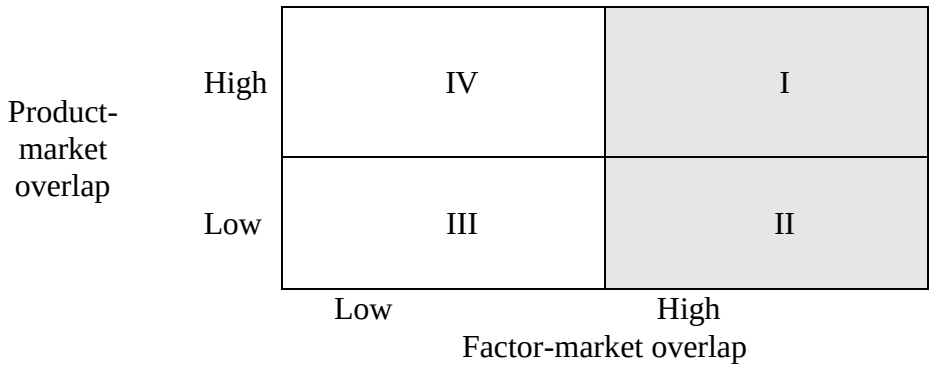

Figure 1 - Matrix of resource- and product-markets overlap (Chen 1996; Markman et al. 2009).

Chen (1996) specify key drivers of competitive behaviour as awareness about interfirm relations and actions of competitors, motivation to act and capability to take action. According to this framework, companies will take actions (or respond to competitor's action) only when they are aware about the problematic situation and have motivation and capability to do so. Capron and Chatain (2008) distinguish two types of strategies at factor market as: focal firm resource oriented strategies (upgrade its own resources) and competitor's resource oriented strategies (degrade rival's resources by reducing the quantity and/or the value creating ability (or efficiency) of available resources). However, Chen and Miller (2015) indicate that the gaining advantage is not always the primary objective of firms. Researchers differentiate three prototypical views of competitive dynamics: rivalrous, competitive-cooperative and relational. Rivalrous view focuses on taking actions that would enable a company to overcome or defend against competitors. Competitive-cooperative approach allows to collaborate with rivals as long as that allows a company to gain competitive advantage. Relational perspective is oriented towards value creation for all parties engaged.

Therefore, to address the posed research questions, it is necessary to examine what constraints companies face from a critical material under consideration (identification of materials criticality) and what actions they take to address those constraints (mitigation of materials criticality). Then, types of competitive strategies (Capron and Chatain 2008) and types of competition (Chen and Miller 2015) allow to characterize the actions taken and to imply about their intentions. The drivers of competitive behaviour (Chen 1996) help to capture the awareness based on expressed risks/concerns by the companies and to argue about motivation and capability to take actions. The impact of the inter-sectoral interactions on identification and mitigation of materials criticality is to be judged based on scope of concerns and mitigation actions in relation to other industrial sectors.

Methodology

In order to examine the posed research questions, a qualitative case study design is employed based on archival data. The paper focuses on examination of REE crisis due to the significance of supply disruption caused by China's export quota restrictions. China is accounted for more than 90% of total REEs production. For the period of 2010-2014 imposed export quota restrictions that limited amount of materials available and led to significant price increases. It provides a case of significant supply disruptions that impacted all companies employing them.

As REEs comprise a group of 17 elements and are employed in various applications. This study focuses on use of REEs in magnets, which is one of the largest applications (22% of global utilisation) (European Commission 2017). Magnets employ two main REEs: neodymium (Nd) and dysprosium (Dy). These two materials are considered in the paper, however, throughout the text the term 'REEs' is used to refer to both materials. Magnets serve in multiple applications, and this study focuses on their utilisation in two of them: generators in wind turbines and electric motors in electric and hybrid vehicles. Consideration of two industrial sectors is important to examine the inter-sectoral interrelations. In particular, three companies are selected: Continental that produces automotive components including electric motors for hybrid and electric vehicles, Vestas that manufactures components and wind turbines and Siemens that has operations in both industrial sectors. Such combination of companies allows examining conditions of the first (high resource market commonality) and the second quadrant (highg resource and product markets commonality) in figure 2.

The data was collected from various secondary sources (e.g. reports, press releases, presentations etc.) publicly available on the webpages of the companies and in the internet. The documents were collected for the period over 2009-2016 in order to consider also the state before the supply restrictions of REEs appeared and to trace the outcomes of the events until today.

The analysis of obtained data was performed based on coding of experienced supply disruption and relevant actions taken, types of competitive strategies and competition. When the coding was completed, the data was analysed in the following way: 1) within each company, for examination of REEs supply constraints, mitigation actions taken, types of actions taken; 2) across companies, for examination of the presence and nature of inter-sectoral interactions, similarities and differences between companies that share only resource market and those that share both markets.

Findings and discussion

The obtained evidence demonstrates that all the examined companies were impacted by REE supply disruptions. The concerns were primarily related to dramatic increase of REEs prices and highlighted over a period 2011-2013. That situation put the companies in a difficult position in relation to their product markets, which were (and still are) characterised by severe price competition and innovation race to advance product performance. Competitive conditions at the product market imposed limitations for REEs disruption mitigation. It was problematic to pass on the price increase to customers due to price competition and contractual obligations (Continental), as well as to stop using REEs, as available alternatives did not allow same functionality and performance of a product (Siemens, Vestas).

In addition, Siemens and Vestas indicated concerns about available volumes of REE and China as a dominant producer. The restrained supply pushed companies to search for alternative sources with lower and more stable prices (Vestas). Siemens put efforts to secure the whole supply chain by establishing partnerships and joint ventures with REEs miners and magnets producers. In addition, Siemens engaged in multiple research projects on development of recycling technology for REEs in permanent magnets in order to create additional local secondary sources of REEs. However, it appears that the examined companies were more concerned about the product market positions rather than resource markets.

Limitations from both supply and demand sides brought companies' attention to optimisation of internal operations. The following actions were taken: product development without REEs or with fewer REEs (Vestas, Continental, Siemens), adjustment of capacity utilisation (Vestas, Continental), production process efficiency (Siemens), development of new magnetic materials (Siemens). The efforts towards REE management initiated in 2011 and took place along the whole examination period. REE crises stimulated increase of monitoring and Siemens even developed own criticality assessment methodology.

The evidence obtained from the examined companies highlights their heterogeneity in the way they experienced REEs supply restrictions and actions taken. The differences are notable within the same industrial sector (Siemens vs Vestas) and similarities are present across industrial sectors (Vestas vs Continental). While Vestas set competitive priorities on cost reduction and therefore focused on manufacture of wind turbines with low amount or no REEs; Siemens chose to compete on functionality and did not withdraw from REEs employment. This again highlights the impact of product market competition on addressing constraints at resource market. As for another example, Vestas and Continental have similar approaches even though they are from different industrial sectors. The similarity is enhanced by similar product market situations and similar nature of the supply disruption. However, in case of more diverse product markets, presence of specific industrial practices (e.g. PGMs price fluctuation is passed on to end customers in the automotive industry) or supply constraints regarding both availability and affordability, the differences could have been significant.

The scopes of concerns and taken actions indicated by the examined companies are limited to a supply chain and/or an industry. For example, although Siemens noted a growing demand for REEs in different applications, this is not reflected anyhow in the criticality assessment methodology or other actions taken. However, Siemens may serve as an example for exploiting cross-industrial similarities for investing in research activities for development of

new magnetic materials and recycling technologies. The large size of the company and operation in different industrial sectors also allows to better balance research investment compensating them by performance of other business units. Vestas provides a contrary example, as at certain point the company decided to pursue only incremental innovations to avoid large cost expenditures and ensure outcomes. Based on the awareness-motivation-capability framework of Chen (1996), it is possible to explain the limited scopes of concerns and taken actions as: the examined companies either do not consider other industrial sector (their demand for REEs) as a potential threat (motivation - Vestas), or do not take it into consideration at all (awareness - Continental), or do not have enough capacity to take actions that would affect other applications (see figure 2).

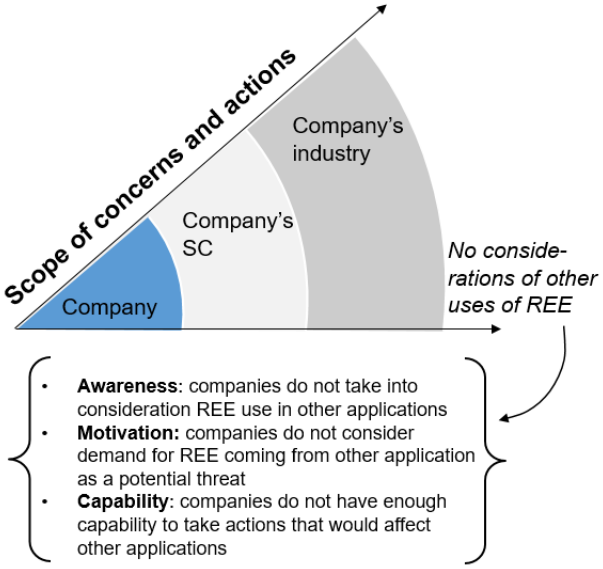

Figure 2 - Scope of concerns and actions of the companies.

Following the classification of Capron and Chatain (2008), the actions taken by the examined companies can be characterized as 'focal firm oriented' or directed to address company's own resources. It appears that the examined companies take actions oriented against the resource market rather than in order to affect a specific company either in the same industrial sectors (same product market), or in other industrial sectors. Companies do not see other industries as competitors, only Siemens pointed out concerns regarding REEs shortage and growing demand for these materials from multiple industrial sectors. Based on Chen and Miller (2015) classification of competition types, the approaches taken by the examined companies may be regarded as rivalrous. The companies engaged in collaborations along supply chains and with research institutes, but not with their competitors.

Although the direct inter-sectoral relations between companies was not found, it does not mean that companies are independent. In particular, the actions taken at the resources market might have indirect effect on other industrial sectors (see figure 3). For example, establishment of a long-term collaborations with a REEs provider (as Siemens did) inevitably limits availability of REEs to other companies. This indicates that industrial sectors that use the same resource are not independent. Therefore, neglecting to consider inter-sectoral relations in the materials criticality assessment might lead to misleading outcomes.

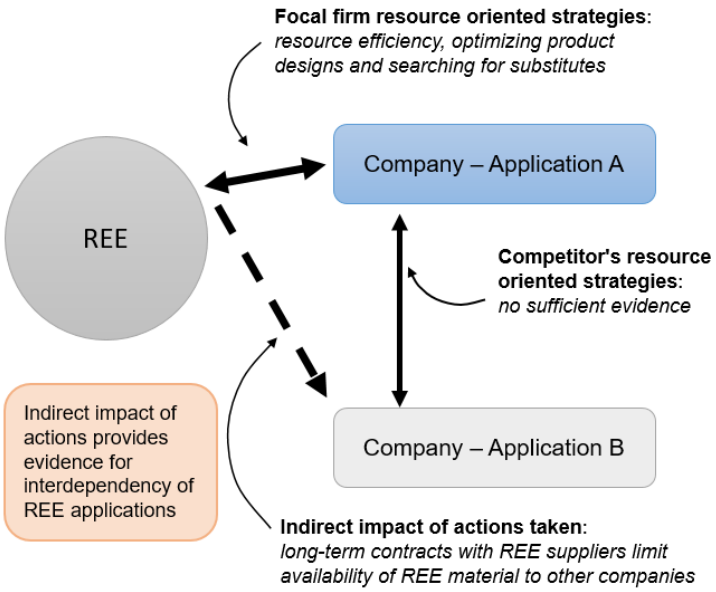

Figure 3 - Competitive environment across applications.

This study highlights the need to advance materials criticality analysis. First, the examination of resource and product markets is required. Both of them impose competitive pressures on companies and may limit the scope of mitigation efforts. This calls for the need of supply chain perspective in the criticality analysis. Second, the examination of inter-sectoral interrelation is required. Even when companies operate in different sectors, they are inevitably interconnected at the resource market. Third, the heterogeneity of companies within and across industrial sectors should be considered, especially for examination of feasibility of mitigation strategies.

Given that the companies have rather limited scope of considerations, the development and employment of own criticality assessment methodology (as Siemens did) is problematic, as it might not consider the full scope of influencing factors. In addition, it might create a perception of irrelevance of studies conducted at the industrial system level. However, development of a company specific methodologies is also a call for policy-makers and researchers to transform the current criticality analysis by incorporating company needs and concerns, by consideration of their heterogeneity and interconnections.

The obtained results provide important implications for policy-makers. The competitive position of national economy at the international arena depends on competitive positions of companies that comprise industrial system. Therefore, if a nation wish to strengthen its international positon, this should be done via strengthening of competitive positions of companies at both product and resource markets. However, development of resources policies should be based on careful examination of heterogeneity and interconnection of companies that comprise an industrial system. The same resource policy may have significantly different impacts on companies within the same industrial sectors and across industrial sectors. Interconnections of companies are not limited to national borders and may span across counties. Therefore, policy interventions in one sectors in a certain country may affect very different sectors in another country.

Conclusions

The paper extends the discourse on materials criticality by examining inter-sectoral interactions between companies that employ the same critical material and the impact of these interactions on identification and mitigation of materials criticality. The obtained results indicate that the examined companies are rather focused on their own industry and supply chain and do not take into considerations other demand for REEs applications as a potential threat to limit REEs availability. It appears that companies take actions to respond REEs market conditions rather than to affect another company. Although the action of companies directly targeted to other applications were not identified, it was possible to notice their indirect effect as they change eventual REEs availability at the market. Therefore, if companies and policy-makers want to secure positions at a resource market, it is indispensable to broaden the scope of consideration to include inter-sectoral interconnection.

The paper brings additional empirical evidence on how companies identify and mitigate materials criticality. Although the paper examines the case of REE crisis, the obtained results provide implications for other materials that are subject to price volatility, supplier concentration, resource nationalization etc. The factor market rivalry proved to be suitable and beneficial lens for examination of inter-sectoral relations of companies.

Further research on inter-sectoral interactions of companies should focus on examination of decision-making process and reasoning behind selection of mitigation actions and mode of interactions with other industrial sectors. Furthermore, it would be beneficiary to engage a bigger scope of companies within and across industrial sectors to investigate contingent factors that trigger differences and commonalities among companies.

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