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Abstract
Purpose – The primary objective of this research is to explore the implications of natural resource scarcity for companies' supply chain strategies.
Design/methodology/approach – Drawing on resource dependence theory, a conceptual model is developed and validated through the means of exploratory research. The empirical work includes the assessment of qualitative data collected via 22 interviews representing 6 large multinational companies from the manufacturing sector.
Findings – When the resources are scarce and vitally important, companies use buffering strategies. Buffering and bridging strategies are preferred when there are a few alternative suppliers for the specific resource and when there is limited access to scarce natural resources.
Research limitations/implications – The research focuses on large multinational manufacturing companies so results may not be generalised to other sectors and to small and medium-sized firms. Future research needs to examine the implications of natural resource scarcity for organisational performance.
Practical implications – This research provides direction to manufacturing companies for adopting the best supply chain strategy to cope with natural resource scarcity.
Originality/value – This paper adds to the body of knowledge by providing new data and empirical insights into the issue of natural resource scarcity in supply chains. The resource dependence theory has not been previously employed in this context. Past studies are mainly conceptual and, thus, the value of this paper comes from using a qualitative approach on gaining in-depth insights into supply chain-related natural resource scarcity strategies and its antecedents.
Keywords Natural Resource Scarcity, Risk Management, Supply Chain Strategy, Qualitative Data Analysis, Case Studies.

Paper type Research paper

1. Introduction

Many firms are dependent on their environment for the supply of natural resources, but these resources are becoming increasingly scarce and costly (Cetinkaya, 2011). The term scarcity refers to an observed shortage of natural resources, and a perceived dependency on natural resources due to their global depletion (Passenier and Lak, 2009). The global demand for materials has increased in recent decades. For example, between 1980 and 2009, global domestic material consumption had increased by 94% up to 67.8 billion tons and it is forecasted to rise (Giljum *et al.*, 2014). Resource depletion or scarcity may be related to economic or physical scarcity, but also to political issues. For instance, China's dominance of the rare earth elements (REEs) market and also the implementation of tax and export quotas, affects the availability, continuous supply and prices.

Concerns regarding the potential shortage of those resources have been reflected on the EU's Raw Materials Initiative, as well as in a number of U.S. legislative efforts to address the rare earth supply (H.R. 761, the National Strategic and Critical Minerals Production Act of 2013, the Critical Minerals Policy Act of 2013-S. 1600). Despite the steady decline in the price for commodities such as metals and minerals, among other things, natural resource scarcity (NRS) remains an important concern and a real risk for both companies and society (Mekonnen and Hoekstra, 2016; Veldkamp *et al.*, 2016).

Several studies (e.g. PwC, 2011; KPMG, 2012) have shown that companies consider the issue of NRS; however, they have not yet implemented any comprehensive strategies to address the associated issues. Research in the field of supply chain management (SCM) has focused on green strategies and sustainability (e.g. Abdul-Rashid *et al.*, 2017; Piercy and Rich, 2015; Seuring and Müller, 2008; Pagell and Wu, 2009), but it has not touched upon issues related to NRS or to the dependence of companies on specific natural resources.

There is a lack of research and empirical evidence of the appropriate strategies to mitigate the risk of NRS (Bell *et al.*, 2012). A recent systematic literature review by Matopoulos *et al.* (2015) highlighted a need for further research on understanding the implications of resource scarcity for supply chain relationships and also its impact on supply chain configurations. The aim of this paper is to increase knowledge regarding the influence of NRS on companies' supply chain strategies. The questions guiding this research are:

> ***RQ1***. *What are the contingent factors that determine the dependence level of manufacturing firms on specific scarce natural resources?*
> ***RQ2***. *What are the supply chain strategies that manufacturing firms can employ to overcome or minimise dependence on scarce natural resources?*

Drawing upon Resource Dependence Theory (RDT), a conceptual framework is proposed to address the implications of the dependence that derives from NRS on supply chain strategies of manufacturing firms. Despite the fact that RDT is a leading theory for understanding organisation-environmental relationships, it is not explored and tested in ways that consider NRS (Stock, 2006; Drees and Heugens, 2013). This is also reflected in recent calls for research which make use of resource theories (Bell *et al.*, 2012; Esper and Crook, 2014). RDT helps to improve the understanding of how supply chains adapt to uncertainty caused by NRS and how they manage resource flows and interdependencies using buffering or/and bridging strategies. The research context is product-based, large multinational manufacturing firms which are more likely to be affected by materials' uncertainty than service firms (Brouthers *et al.*, 2002).

The next section incorporates a literature review highlighting existing research on NRS and RDT that provides a useful foundation for development of the conceptual framework. The research design and explanation of how data were collected and analysed are then discussed. The section following the methodology develops the framework and the research propositions based on the empirical findings and RDT. The paper concludes by pointing out theoretical and managerial implications as well as further research opportunities.

2. Literature review and theoretical background

Christopher (2016) noted several major trends impacting contemporary supply chains including the globalisation of markets, outsourcing, the reduction of the supplier base, shorter product and technology life cycles, fewer and larger production and distribution sites, volatility of trading environment and vulnerability of supply chains leading to disruption. Several authors including Christopher and Peck (2004), Gualandris and Kalchschmidt (2013), Peck (2005), Sheffi (2005), Svensson (2002), Vlachos *et al.* (2012), Wagner and Bode (2006), and Waters (2011) focused on supply chain vulnerability. In addition, Peck (2005) explored the sources and drivers of supply chain vulnerability while Stecke and Kumar

(2009) proposed several strategies to mitigate the vulnerability of a supply chain. Other authors analysed the issue of uncertainty and risk in supply chains in general (Simangunsong *et al.*, 2012) and specifically in relation to NRS (Bell *et al.*, 2013).

NRS concerns were first expressed in the mid-1980s under the concept of sustainability or sustainable development (Krautkraemer, 2005). There has been a growing interest in sustainable supply chains for over a decade and this field is now becoming more mainstream (Fabbe-Costes *et al.*, 2014; Sarkis *et al.*, 2010). Many authors have defined sustainable SCM (e.g. Srivastava, 2007), developed frameworks of sustainable SCM (e.g. Carter and Rogers, 2008) and explored this area from different SCM perspectives such as the influence of power on sustainability practices (Touboulic *et al.*, 2014). These studies have also highlighted the need for securing sustainable sources of key raw materials to secure business continuity and the subsequent cost- and reputation-related challenges.

Natural resources are defined by the World Trade Report (2010, p. 46) as "stocks of materials that exist in the natural environment that are both scarce and economically useful in production or consumption, either in their raw state or after a minimal amount of processing". Some resources such as water, land, crops, timber, and fisheries etc. can be renewable and other resources such as minerals, metals, organic resources are non-renewable meaning that once depleted they will not be available for future use (Mildner *et al.*, 2011). For this manuscript, the terms resource(s) and natural resource(s) are used interchangeably with an emphasis on REEs, water and energy[1].

During the past few years, a series of events including the export restrictions by China in 2011 drove up prices of REEs. However, this was temporary and since 2013 the prices of REEs have declined. Overall, industry and governments are concerned about price

[1] Energy refers to the primary energy sources such as crude oil, natural gas (non-renewable sources) and solar energy, wind energy, biomass resources (renewable sources).

fluctuations and the smooth supply of these raw materials due to various measures taken by the Chinese govemerment to limit REE production (Pavel *et al.*, 2017). Water is another important natural resource for nearly all industries including automotive, beverage, chemical, electronics and metal mining (Chernock, 2013). Water scarcity poses a higher risk to businesses than oil (Morrison *et al.*, 2009) and this risk is expected to increase in many regions due to population growth, climate change, urbanisation and changing lifestyles (Jefferies *et al.*, 2012). For example, a Coca Cola plant in Plachimada which is located in southern India was shut down due to water scarcity (Tercek and Adams, 2013).

Similarly, there is competition over energy resources (Sovacool, 2009) that impacts on energy intensive sectors such as aluminium, chemicals and food (Zero Waste Scotland, 2011). In this context, manufacturing companies have to be able to manage their dependencies and to consider them during the formulation of their supply chain strategies to minimise the negative effects of potential distruption (Bode *et al.*, 2011). NRS can put supply chains at risk if managers fail to address the serious issues that are introduced (Bell *et al.*, 2013). For example, the automotive industry faces indirect effects considering the rising prices of natural resources as a car consists of steel, non-ferrous metals, polymers, rubber and glass (European Commission, 2011). Dyer (1996) also found that automotive firms are dependent on specialised supplier networks.

Despite the fact that bauxite or aluminium ore are abundant, aluminium production is highly sensitive to energy prices and legislation (Circular Economy Task Force, 2013). For example, Vedanta was forced by an Indian court to stop mining to feed an alumina refinery in the Indian state of Orissa due to environmental regulations and social forces. Local environmentalists and activists legally stopped mining bauxite as it was violating the Indian Forest Conversation act and the Dongria community who are a small number of indigenous people (Peoples and Bailey, 2012). Recently, China's "Air Pollution Control" regulation formally came into effect and it will force aluminium smelters to reduce output which will lead to price fluctuations (Home, 2017).

Subsequently, there have been some efforts in the past to identify the implications of NRS on manufacturing supply chains (Alonso *et al.,* 2008; Alonso *et al.*, 2009; Alonso, 2010; Alonso *et al.*, 2012; Autry *et al.*, 2013; Bell *et al.*, 2012, Bell *et al.*, 2013; George *et al.*, 2015; Lapko *et al.*, 2016); nevertheless, there is still a need for further research. One of the main limitations of the research conducted to date is that it is conceptual and not empirically tested and for a richer understanding and validation, empirical research is needed. This argument is supported by Bell *et al.* (2012) who highlighted the need for industry case studies to recognise and implement creative supply chain strategies to altering natural resource availabilities.

In addition, the selection of appropriate strategies for the use of different natural resources and the inherent natural resource depletion is limited in current research. Scholars focus mainly on recycling (Alonso *et al.,* 2008; Alonso *et al.*, 2009; Bell *et al.*, 2013) as a mitigation strategy of natural resources such as platinum, or cobalt (e.g. Alonso *et al.*, 2009). However, the degree of dependence on various scarce natural resources has a number of causes and thus companies may need to adapt and utilise different strategies.

Overall, research in this domain is not grounded in theory with the exception of research by Bell *et al.* (2013) who propose an empirically testable model based on the resource advantage (R-A) theory. This is a key limitation in SCM research which has been highlighted by many researchers (Flint *et al.*, 2005; Kovács and Spens, 2005; Mollenkopf *et al.*, 2010). RDT is chosen for this research, because the topic considers scarce natural resources which may be of strategic importance and, subsequently, they are usually owned by countries and companies trying to control them (Waters and Rinsler, 2014). RDT was developed by Pfeffer and Salancik in 1978; it considers resources as crucial in order for companies to implement a business strategy and generate a competitive advantage.

Previous studies (e.g. Carr *et al.*, 2008; Kähkönen *et al.*, 2015) applied the lens of RDT in the field of SCM to investigate collaboration and bargaining power in times of uncertainty but without focusing on specific resources and without considering the inherent uncertainty arising from NRS. According to RDT, organisations are not self-sufficient and embeddedness in a network of relationships is a response to the uncertainty involved in a relationship and the resource dependence (Pfeffer and Salancik, 1978). The degree of dependency emanates from three contingent factors (Cannon and Perreault, 1999; Pfeffer and Salancik, 2003; Caniëls and Gelderman, 2007): a) the importance of the resource such as the degree to which a purchased resource is critical to manufacture other parts, components, or end-products, b) supplier substitutability such as the availability of alternative suppliers that supply the resource and the relevant switching costs and, c) the discretion over the resource that can be determined by the ownership of the resource.

RDT suggests that these three factors lead to either buffering and/or bridging strategies. According to Leonardi (2013), buffering strategies are used to redefine goals to minimise resource dependencies on other firms and reduce the uncertainty of obtaining important resources; hence, buffering strategies can be employed in connection with many operational challenges including those related to inventory. Bridging strategies can reduce the chances of resource shortage by strengthening the links and building bridges between the firm and other organisations including, for example, the collaboration between firms or even acquisitions. Buffering and bridging activities are not mutually exclusive. An organisation may increase its safety stock of a strategic natural resource following a buffering strategy and, simultaneously, it could establish collaboration with a supplier of this scarce natural resource following a bridging strategy (Bode *et al.*, 2011).

3. Methodology and research design

3.1 Research approach

Due to the exploratory nature of this research, a case study methodology was selected. Case study is the most suitable methodology where the goal is to refine a less theorised area of knowledge, based on empirical observations (e.g. Eisenhardt, 1989; Ketokivi and Choi, 2014; Walker *et al.*, 2015). Theory elaboration was used because this research focuses on a contemporary phenomenon, i.e. extending the understanding of the implications of NRS on manufacturing companies. Theory elaboration is based on the interplay between theory and the empirical data from case studies that enhance theoretical insights (Ketokivi and Choi, 2014). The combination of RDT, relevant literature and empirical data provide a sufficient basis for building a conceptual framework and formulating propositions.

A multiple-case study method and replication logic were adopted to help discover similar or contrasting results with regards to the contingent NRS factors and the respective supply chain strategies. The case studies are guided by relatively open research questions but not by a priori propositions.

3.2 Case study data collection and analysis

The theoretical constructs explored in this study were related to a focal manufacturing firm. The case selection was driven by the research questions, and a purposeful selection procedure was conducted. Merriam (1998, p. 61) notes that: “Purposive sampling is based on the assumption that one wants to understand as much as possible, and thus the sample is selected deliberately in a way that most can be learned”. The case studies were selected based on theoretical sampling and not on random sampling (Eisenhardt, 1989) and the case study companies were selected on the basis of their overall ability to provide information on the subject. More specifically, the companies were selected considering that they make use of REEs (water or energy natural resources) and they are actively trying to manage their dependencies which, in turn, informs the formulation of their supply chain strategies. The selection was also influenced by the practical feasibility of getting access to case study companies, i.e. willingness of managers to participate in the research and their availability for an interview.

We attended relevant industry conferences and we gathered the delegate lists to identify appropriate managers ; one of those was the conference organised by the Aluminium Federation in the UK. Business cards were collected and networking arrangements took place during these conferences. LinkedIn, a professional networking site, was also used to find cases. Managers working in manufacturing companies possessing knowledge within the purchasing, sustainability, supply chain and logistics were approached. A search was also conducted for relevant groups on LinkedIn in order to target these professionals. Access was gained to relevant groups in LinkedIn including Manufacturing UK, Beer Industry Members, Chartered Institute of Purchasing and Supply (CIPS). An email or a personal LinkedIn message was sent to relevant managers currently employed in the automotive and aluminium industry asking them to participate in an interview.

The result of this search was the inclusion of data from 6 cases representing large[2] multinational companies (two original equipment manufacturers [OEMs], one manufacturer of automotive Body-in-White products and services, one manufacturer of seats, and two manufacturers of aluminium). We need to clarify that we did not consider SMEs in our work primarily because these companies do not widely adopt and develop sustainable and resource efficient supply chain practices due to the time, resources or information required (see for

[2] The European Commission considers SMEs as companies with less than 250 persons employed and an annual turnover of up to €50 million, or a balance sheet total of no more than €43 million (European Commission, 2005).

example, Bourlakis *et al*., 2014). RDT also supports that larger organisations utilise more resources that can help them to avoid dependence. According to Pfeffer and Salancik (1978, p. 131), size "provides organizations with additional control over their environments and enhances their likelihood of survival". In general, large companies follow a set of global standards and principles in their production facilities in relation to environmental policy and NRS dimensions to accommodate pressures from external stakeholders and to manage global risks successfully (Christmann, 2004). The specific unit of analysis for this research is the firm that uses scarce natural resources for semi-finished or final products as our goal was to explore manufacturer perceptions of NRS implications. Tables 1 and 2 provide details for the industry, the number and profiles of interviews per company.

<<Table 1>>

<<Table 2>>

Data was collected through qualitative, semi-structured in-depth interviews (22 in total) which is the most widely used across all qualitative methods as it gives insights into how respondents see their world (Easterby-Smith *et al.*, 2004). A list of pre-defined, openended questions was developed (see Appendix A). The interview questionnaire was pretested with two academic experts and one practitioner with relevant experience to ensure content validity and some changes were made regarding the adoption of "more business" language and the definition of some of the concepts. The same research protocol applied to all respondents in order to ensure transparency and repeatability of research. Participants were encouraged to provide extensive and developmental answers to expose attitudes or obtain facts (Saunders *et al.,* 2003). In addition, interviews with experts from the aluminium industry and a consultant with expertise in REEs were conducted to validate some of the managers' responses in the automotive and aluminium industry.

The interviews were conducted face to face in the UK manufacturing plants of the case companies except one which was conducted in the head office in Norway via telephone. The decision for conducting the interviews in the UK was due to the geographical proximity of the researchers and the potential to secure access to the organisations involved. Also, many automotive and aluminium manufacturers have a major presence in the UK making the manufacturing plants a good proxy for their global operations. The time for each interview ranged from 30 minutes to 1 hour. All interviews were voice recorded and transcribed except one (i.e. AutoCo_1).

The interviews were anonymised and then imported to NVivo for analysis. QSR NVivo software version 10 was used for the qualitative analysis as it is an effective computer software for coding data (Garza-Reyes, 2015). Coding was done independently by one researcher from the team of authors, and verified by the other authors to maintain rigor, to reduce interpretive bias and increase the reliability of findings in this process (Berg, 1998). When disagreements took place relative to the coding, the data were revisited and the authors were engaged "in mutual discussions for arriving at consensual interpretations" (Gioia *et al.*, 2013,p. 22). The transcriptions were read several times in order for the researchers to understand and become familiar with the data.

The content components which include the elements that were analysed and coded, were the sentences in the transcript files. As part of within-case analysis, each case was individually analysed. The interview transcripts were analysed in waves and a code was assigned to a phrase giving evidence towards answering the research questions. Then, a cross-case content analysis was employed to compare and contrast the responses and to understand the commonalities and differences in patterns for strategies utilised for various natural resources and to reach generalisations across the six cases (Miles and Huberman, 1994).

The data were systematically analysed and iteratively coded (see Appendix B) following three coding stages (Gioia *et al.*, 2013). Open coding was used initially to identify and to categorise the data as well as to generate the first-order concepts. This was followed by axial coding where first-order themes were connected with second-order themes and selective coding where the aggregate dimension was chosen to be the core category and all other second-order themes were related to that category (Corbin and Strauss 2008; Corley and Gioia, 2004). The second order themes and aggregate dimensions were derived from theory while the first order themes were added during the process of analysis which captured broad themes such as the price of the natural resource.

To ensure objectivity, validity, and reliability of the content analysis, pre-defined categories were developed based on the theoretical framework (Spens and Kovács, 2006). The use of NVivo 10 facilitated the coding process by recording the codes and led to effective data management, organisation and analysis (Kuckartz, 2014). Through the analysis of the three coding stages, certain patterns were revealed, the coding bias was minimised and credible interpretations of data were made (Barratt et *al.*, 2011; Yin, 2003).

Secondary data such as companies' sustainability reports and information on sustainability strategies were collected and used to find new information or to verify the information provided by key informants. This is an acceptable practice in SCM as managers/respondents do not always know specific details including key performance indicators (Cuthberson and Piotrowicz, 2008; Calantone and Vickery, 2010). These techniques allowed for triangulation of the interview data providing reliability and internal validity of research findings (Yin, 2003).

4. Empirical Findings

This section begins with an overview of the results from the within-case analysis for the 6 case studies and in the following section, the themes that emerged from the cross-case content analysis are presented. The implications of the natural resource dependence level on supply chain strategies are then discussed along with the derived research propositions.

4.1 Within case analysis

AutoCo_1: Interviewees suggested that the price of the natural resource, the number of suppliers, switching costs, legislation and geopolitical risk are the key dependence factors. The case revealed that the importance of natural resources including a high price leads primarily to buffering supply chain strategies such as substitution. For instance, the company tries to reduce the dependence on petroleum oil (and thus reduce the carbon footprint) by using renewable resources such as soy-based polyurethane foams for automotive applications. Regarding bridging strategies, AutoCo_1 has primarily single source supplier contracts that last about twelve years .

For example, AutoCo_1 closely collaborates with the wiring connector supplier. The supplier located its plant close to the automotive company so that AutoCo_1 can be involved in the design of the part. For water utilities, energy and recycling of the materials, short-term contracts are used with suppliers. Apart from the issue of accessibility to REEs, AutoCo_1 is also concerned about conflict minerals and, therefore, it is working closely with suppliers globally that provide parts and it requires from them to support this effort.

AutoCo_2: This company recently started to apply some strategies for minimising the use of resources. The main reasons for following these strategies are the price of the resources, the number of suppliers and legislation. By working closely with its customers, AutoCo_2 reduced the usage of aluminium. Specifically, it collaborated with an aluminium supplier in an attempt to increase its recycling and, therefore, this specific supplier provides AutoCo_2 with aluminium that has a higher content of recyclable material. A new technology was also introduced to replace welding which, in turn, reduced energy consumption by not using heat. Welding uses a lot of energy, but recently many motors and parts are utilising low energy pumps and heating equipment. In the coming years the company is considering taking a closer look at water as a resource.

AutoCo_3: According to the interviewees, the price of the natural resources, quantities of the natural resource, the number of suppliers and switching costs, the geopolitical risk, and legislation are the main factors that create dependence on resources. AutoCo_3 increased the quantities of recycled aluminium in order to reduce energy usage and to reduce CO_2 emissions by creating a closed loop system and by collaborating closely with its aluminium supplier. It is also trying to find new types of natural fibres such as sugar and to replace plastic that is oil based. AutoCo_3 consumes a lot of water in the painting shops and a few plants recycle water from the paint shop and reuse it in their manufacturing processes.

The company is trying to use renewable sources more extensively including biofuels. Advanced combustion technology will be used in one of its plants that would burn waste wood in order to fulfil most of the site's electricity needs. AutoCo_3's managers recognise that it is not an easy process to find alternative suppliers as there are costs and specific requirements regarding material standards; so it mainly follows relational mechanisms. Concerning accessibility, the practice of relocating its existing plants is not considered as a possible strategy. However, for its future plants, AutoCo_3 is planning to manufacture cars in Saudi Arabia because of the huge quantity of aluminium that exists in this country and it is also considering building a factory in Brazil to have access to the massive amounts of copper non-ferrous metals and petrochemicals. AutoCo_3 is starting to recognise the limitations in the availability of specific materials to its product, e.g. lithium batteries where materials are provided by China and Russia; therefore, AutoCo_3 is getting slightly concerned for the inherent challenges to obtain access to those materials.

AutoCo_4: As in the previous cases, cost was identified as one of the most important factors as well as the quantity of the natural resource, switching costs and legislation. There are two paint lines that are using a great amount of water so the water in these processes is being recycled. Another strategy followed by this company is the recycling of scrap metals or plastics. Chairs are being manufactured from recycled or recyclable materials too. Regarding bridging strategies, the company pursues long term agreements with its key suppliers and most of the other purchases are managed by a nomination and purchasing order. AutoCo_4 has also signed a contract with a waste management company for resources such as metal, plastics, cardboard.

AlumCo_5: There are four main factors that were identified as the most important ones leading this aluminium company to specific strategies including the price of the natural resource, the number of suppliers, social forces and geopolitical risk. The high value of aluminium scrap leads the company to investing in improving productivity (increase remelting capacity) in existing cast houses but also they build new ones. Scrap is sent to external cast houses to re-melt if there is an issue from a logistical point of view. In some plants in Europe, AlumCo_5 has installed solar panels in order to use more renewable resources and to use less energy. In India, the company has buffers of energy such as electric generators to support its business continuity.

Water is used mostly in the phases of rolling, extrusion, anodising and painting but it is not a significant amount. Water reservoirs are utilised and rain water is part of the solution to reduce the implications of water scarcity. Energy is highly regulated and, in most countries, there is only one supplier that can offer this natural resource; the same applies to water, however, the company is usually having shorter term contracts with water suppliers.

AlumCo_5 tries to use hydropower from Norway, Siberia and Iceland and Canada but it is currently dependent on suppliers from the Middle East. Relocation from China to Europe is not possible either considering that the European energy market is highly regulated and making it costly to produce aluminium in Europe.

AlumCo_6: The price of energy, the large quantities of aluminium, switching costs and legislation are the main contingency factors that the company considers. The main strategy followed by the company is the recycling of scrap aluminium. It has built a recycling processing facility for scrap cans and other aluminium waste produced into sheet and rolls and this leads to an effective closed-loop system supported by established collaborations with its customers. Renewable and nuclear energy represent 30% and 23% respectively of its total electricity consumption . One of its plants in America has its own hydroelectric facilities to provide power.

Apart from utilising new energy resources, AlumCo_6 tries to produce existing equipment more efficiently. In its UK factories, the lighting system has been upgraded to LEDs and two older compressors have been replaced with energy efficient ones. Changes have also been made in melting and producing processes. For example, the furnace burner technology was upgraded and burners were replaced. Another example is that standard efficiency motors were changed with high-efficiency models. Regarding water scarcity, water use in the casting of ingots after re-melting recycled materials has been optimised and monitors have been installed in order to control the water usage in the cooling operations. Water usage is reduced by repairing leaking water pipes, installing temperature monitoring in order to control cooling operations. Water is reused and recycled, for example, through cooling towers in one of its UK factories.

4.2 Cross-case content analysis

As noted in Section 3, the use of NVivo 10 facilitated the coding process resulting in fifteen categories examined below. Before discussing the implications of the dependence level on supply chain NRS strategies further, it is important to have a clearer picture of the overall factors that define the dependence level and the strategies that companies follow to respond to it. Seven key factors emerged from the interview transcripts that define natural resource dependence level. Some of these factors, which are highlighted in bold below, are related to the "discretion over the scarce natural resource" and it is worth stressing that these have not been identified in previous research:

i. the price of the natural resource (AutoCo_1, AutoCo_2, AutoCo_3, AutoCo_4, AlumCo_5, AlumCo_6),

ii. the quantity of natural resource (AutoCo_4, AlumCo_6),

iii. the availability of alternative suppliers for the natural resource (AutoCo_1, AutoCo_2, AutoCo_3, AlumCo_5),

iv. the switching costs associated with switching suppliers that provide the natural resource (AutoCo_3, AutoCo_4, AlumCo_6),

v. **legislation** (AutoCo_1, AutoCo_2, AutoCo_3, AutoCo_4, AlumCo_6),

vi. **geopolitical risk** (AutoCo_1, AutoCo_3, AlumCo_5), and

vii. **social forces** (AlumCo_5) that can hinder the ownership of the natural resource, the ability to access and use the natural resource.

Several supply chain strategies were utilised to minimise the resource dependence level for the 6 companies. More specifically, firms follow buffering strategies such as dependency reduction or bridging strategies such as dependency restructuring (Green and Welsh, 1988). Based on the empirical data, 8 supply chain NRS primary strategies emerged (themes are highlighted in bold) that have not been identified previously in the NRS literature and in previous research related to RDT in SCM. The buffering strategies refer to **product and process (re-)configuration** including **new technologies to minimise the usage of resources in the product, the use of substitution and recycling** as well as **supply chain (re-)configuration** covering **safety stock and plant relocation**. Whereas, the bridging strategies entail long-term contracts that establish supply and price over an extended period. These include **transactional mechanisms** as well as partnerships and joint ventures, **relational mechanisms** or even **vertical integration**. There are also hierarchy mechanisms "*in which, for example, a producer buys out a supplier and gains control of the critical resource*" (Jaffee, 2010, p.8). Common patterns in the case studies were assessed and the literature and theoretical justification of RDT were used to formulate the conceptual framework. The research propositions derived from the data and the literature are provided in the following sections.

4.3 Importance of the scarce natural resource and supply chain NRS strategies

Resource importance is the key determinant of buffering strategies as found in the prior literature (Meznar and Nigh, 1995). The interviewees supported that the price of the scarce natural resource and the quantities of a given resource lead companies mainly to buffering strategies. This is primarily through product and process (re-)configuration such as recycling, new technologies and substitution to reduce the importance of natural resources such as water, energy and aluminium.

Product designers are motivated to minimise the use of certain natural resources by substituting them with other natural resources or by using recycled materials (Lin and Lin, 2003). Companies introduce improved products or processes to minimise or overcome the usage of scarce natural resources. The introduction of new technologies is a common strategy to minimise resources such as water and energy. For instance, in AutoCo_1, the Purchasing Manager states: *"We changed the cooling system and we will move from metal-halide to LED lighting in order to reduce annual energy consumption". Moreover, "We moved to dry paint overspray system that uses more paint but less water"*. Companies in the brewing industry are using large quantities of water. For example, Miller Coors, (a joint venture of SABMiller PLC), installed cameras inside one of the process vessels in its brewery in California to cut off the water supply as large amounts of water were used for beer production (Wales, 2013).

Substitution is also followed by companies and most of them including AutoCo_2 and AlumCo_6 try to use alternative sources of energy such as wind turbines and solar energy. AutoCo_1 tries to minimise the dependence on petroleum oil by using renewable resources such as soy-based polyurethane foams or a tropical plant, to reinforce plastic and to substitute the oil-based resin in the plastic. Companies that cannot find substitutes often alter the structure or inputs by using strategies such as recycling, inventories and minimising the resource usage (e.g. AutoCo_1, AlumCo_6).

AlumCo_5 has initiated a closed loop programme for old aluminium light poles including fittings and cabling with a few Norwegian cities. *"So instead of buying new metal, we are trying to recycle and reuse scrap"* (Director of Global Strategic Sourcing). AutoCo_4 has also initiated a program with its aluminium supplier who is responsible to take back the scrap that is produced through the stamping processes. *"We have a system where any scrap metal aluminium and steel is segregated and sent back to suppliers for recycling"* says the Sustainability Manager. Safety stock as strategy is used for certain resources such as water but it is not preferred for metals and REEs due to price volatility and because it ties up cash unnecessarily (e.g. AutoCo_1, AutoCo_3, AutoCo_4). AutoCo_4 Sustainability Manager states that *"we consume a lot of water especially in the painting shops and few of our plants* *stores the rainwater for reuse in our manufacturing processes"*.

Therefore, when the resource is critical, companies try to make it less important by utilising buffering strategies; they are used to minimise the importance of the valued resource and, thus, the level of resource dependence by altering or minimising the resources used for production (Bode *et al.*, 2011; Scott, 2003). Buffering strategies entail the use of flexible production processes, product designs and safety stocks or a higher level of inventory (Bode *et al.*, 2011) and they are often employed when a firm face uncertainties that hinder the production processes (Carlile *et al.*, 2013).

The findings revealed that when the natural resource is important the companies do not follow bridging strategies. When there is an uncertainty and high dependence on the supply of a critical natural resource that threatens an organisation to continue functioning, companies minimise or avoid these resources rather than developing a relationship with the supplier of this resource (Pfeffer and Salancik, 1978). This is also supported by other studies such as the one by Meznar and Nigh (1995) who found that the importance of resource is negatively associated with public affairs bridging. This leads to the development of the following propositions:

P1a: The importance of scarce natural resource is positively related to the adoption of buffering strategies.

P1b: The importance of scarce natural resource is negatively related to the adoption of bridging strategies.

4.4 Supplier substitutability of scarce natural resource and supply chain NRS strategies

When companies do not have many suppliers or the switching costs are high and therefore, there is low supplier substitutability, bridging strategies are preferred. In the automotive sector, the Purchasing Manager of AutoCo_1 states that: *"our supplier base is reduced and we usually use single-sourcing"* while another Purchasing Manager of AutoCo_1 notes that they: *"usually have long term contracts up to 5 years"*. AutoCo_2 has identified the limited number of suppliers as a key contingent factor that leads to relational mechanisms and their Logistics Manager mentions: *"It's limited where you can go and buy";* thus, companies tend to collaborate or have long term relationships for several years.

Collaboration has become a new mantra to address the issue of volatility that derives from NRS (Bell *et al.*, 2013; Lapko *et al.*, 2014). Johnson *et al.* (2011) state that scarcity results in individuals and communities being willing to participate in alliances in order to escape resource imbalances. Based on the findings, there is a strategic partnership of AutoCo_1 and a supplier of wiring connectors where they jointly discuss challenges and work together while both firms are involved early in the design of the part implying the use of buffering strategies. The Vice President (VP) of Strategic Sourcing of AlumCo_5 also stressed that in the aluminium production: *"there are not really many alternatives...most of our metal is coming from the long-term strategic partner"*.

Apart from the number of suppliers, switching costs are important too. The Sustainability Manager of the AutoCo_4 highlighted that: *"it's not an easy process, we have to go through various steps including a lot of verification tests to ensure safety, you need to make sure that a new supplier or a different supplier is able to meet all company's requirements"*. AutoCo_2 collaborates with the nominated supplier of aluminium on closing the loop by recycling their own process scrap: "*So what will happen is that our scrap will be sent to the nominated supplier and then the scrap goes back to a melting cast, once melted, the aluminium is cast and rolled and finally delivered to us* (Purchasing Manager)." Previous studies show that there is a positive relationship between buyer dependence and the choice of bridging strategies (Bode *et al.*, 2011; Su *et al.*, 2014; Wu *et al.*, 2004); however, they did not specify the type of buyer-supplier relationships.

Reverse logistics could change supply chain (re-)configuration i.e. buffering strategies in which a company must determine the collection/acquisition centers, inspection/sorting centers, disposal facilities etc. (Ene and Ozturk, 2014). Managers from AutoCo_1, AutoCo_3 and AlumCo_6 have discussions with managers from their suppliers to implement systems that will enable them to have access to end of life vehicles which means access to valuable resources such as aluminium and gold. However, recycling of rare earth metals that also demands less energy than primary mining activities is not used as a mechanism to secure those resources from companies because of inefficient collection systems, technological issues and lack of incentives. This is supported by Lapko *et al.* (2016) who noted that recycling of rare earth metals is not feasible or relevant for business.

All cases show that for water and energy suppliers, transactional mechanisms are adopted. Water and energy supply is not substitutable and suppliers have monopoly control on those natural resources needed by manufacturing companies. The Purchasing and Logistics Director of AutoCo_2 company states that: *"Consumable contracts for water, gas, power will be reviewed normally under 2-3 years fixed contracts for the utilities dependant upon the best deal we can get and later we will check the open market and maybe change the supplier"*. The Plant Manager of AlumCo_6 also notes that: "*Where we have interdependencies we work closely with our strategic partners*".

Thus, when few suppliers sell resources, supplier concentration increases and uncertainty increases as the dependence on fewer suppliers that control most resources is increased and bridging strategies are used (Pfeffer and Salancik, 2003). Contrary to what has been suggested by previous studies, this work revealed a positive relationship between substitutability of suppliers and product and process (re-) configuration as part of a buffering strategy. This insightful finding stresses that companies collaborate with a few key suppliers that are involved in the product development at an earlier stage. This is also supported by other studies (Demeter *et al.*, 2006).

There is also considerable uncertainty in relation to firm size. Smaller firms may be more inclined to develop formal types of collaborative activities to gain better access to critical resources (Guo and Acar, 2005). Large firms, on the other hand, have sufficient resources, and can "alter their contexts in a significant fashion" (Pfeffer and Salancik, 1978, pp. 267) and by controlling important resources, these firms could engage in more buffering activities (Meznar and Nigh, 1995). Hence, it is proposed:

P2a: Supplier substitutability is negatively related to the adoption of buffering strategies.

P2b: Supplier substitutability is negatively related to the adoption of bridging strategies.

4.5 Discretion over scarce natural resource and supply chain NRS strategies

Discretion over natural resources can be determined by the ability to access, use, and own the scarce natural resource. During the empirical exploration it is found that discretion can be hindered by government regulations, social forces and geopolitical risk. The key findings of the cases suggest that if the accessibility is disrupted for a given natural resource, companies are following a combination of buffering and bridging strategies namely recycling, substitution or close collaboration.

In all six case studies, participants revealed that environmental legislation and geopolitical risks are key drivers for manufacturing companies to follow the practices of product, process and supply chain (re-)configuration. Due to energy pricing and carbon taxation, Europe has become less interesting for companies to smelt and cast aluminium.

European Emission Trading Scheme (EU ETS) can lead to company relocation. This scheme allocates a certain amount of carbon to use and companies from the aluminium industry are less likely to invest in Europe, they will probably move to China or India. This is supported by the UK Environmental Manager of AutoCo_4 who notes: *"there is a government legislation that is called ESOS where if a company is bigger than 250 employees, it must have a plan in place at the end of the year to reduce energy consumption within the building"*.

Big aluminium factories such as the Anglesey aluminium plant have shut down because of environmental legislation (Merlin-Jones, 2012). *"A Brazilian plant was shut down five years ago due to high energy usage and we still have concerns over the energy and water usage so we try to minimise the water use in the casting of ingots after re-melting recycled materials; monitors have also been installed in order to control the water usage in the cooling operations"* (Plant Manager of AlumCo_6). "*If you look at the aluminium industry the most efficient smelting capacity is being built where there is access to cheap power, in places like Scandinavia or Canada where there is hydroelectricity or places like the Middle East where oil is cheap"* (Vice President of Strategic Sourcing, AlumCo_5).

AutoCo_3 realises the geopolitical risk of metals and REEs so the firm has created "*a closed loop system where basically aluminium is coming from the production line"* (Sustainability Manager). AutoCo_1 utilises a different buffering strategy for metals as the Purchasing Manager notes: *"Specifically we try to use the minimum of a scarce natural resource such as gold … and we mix it with other resources that are not considered to be scarce"*.

RDT considers partnerships as the means to gain access to resources from the environment and to manage environmental uncertainty that is a high control strategy (Sherman, 2007). Companies are starting to collaborate or vertically integrate with their suppliers through mergers and acquisitions to gain access to scarce and critical resources for their survival. This is further illustrated by taking into account the fact that Toyota has secured lithium supply for battery packs through a joint venture with a lithium Australian mining company called Orocobre (Orocobre Limited, 2010). Toyota also collaborates with Indian Rare Earth in Orissa, Vinacomin in Vietnam and Sojitz in Japan (George *et al.*, 2015). According to Pfeffer and Salancik (1978), the first option to get more discretion over resources is possession, which can be achieved by vertical integration. AlumCo_5 acquired an aluminium casting plant in The Dalles (Oregon, USA).

Bridging is used to obtain discretion over scarce natural resources. Bridging, as defined previously, entails long-term contracts that establish supply and price over an extended period, and/or partnerships and joint ventures (Jaffee, 2010). Moreover, buffering strategies are utilised namely for product and processs (re-)configuration and supply chain (re-) configuration. Product and processes (re-)configuration is practised by companies to reduce natural resource usage (Delmas and Pekovic, 2013). Firms need to understand the benefits they would gain if they concentrate on their product and processes (re-)configuration simultaneously with the supply chain (re-)configuration decisions (Fine, 1998).

Concerning supply chain (re-)configuration, safety stock is a common buffering strategy that is followed in order to minimise dependence on resources (Bode *et al.*, 2011; Su *et al.*, 2014). Facility location decisions need to be considered too. As far as NRS is concerned, it may force companies to design their networks based on proximity of scarce natural resources or to relocate factories in other regions to access scarce natural resources. Based on the above, it is proposed:

P3a: Discretion over scarce natural resource is negatively related to the adoption of buffering strategies.

P3b: Discretion over scarce natural resource is negatively related to the adoption of bridging strategies.

The conceptual framework in Figure 1 is composed of the above six propositions and it is divided into two parts: the first part identifies the natural resource dependence level. The second part deals with the supply chain-related strategies that companies may adopt to minimise the natural resource dependence level.

<<Figure 1>>

The research applies this type of cross-case analysis to validate the framework and show the effect of each second-order theme of the natural resource dependence level on supply chain NRS strategies as an aggregate dimension. In Table 3, the cross-case matrix is shown illustrating the strategies companies follow to respond to the dependence level in connection with the scarcity of natural resources. Table 4 illustrates the causality of the propositions developed for the association between natural resource dependence level and supply chain NRS strategies.

<<Table 3>>

<<Table 4>>

5 Conclusions and implications

This research set out to answer the following questions: why and how do manufacturing companies respond to the growing competition for scarce natural resources? This research develops and empirically tests an RDT-based conceptual framework that aims to understand the NRS implications for SCM. In relation to the first question, the seven factors that determine the level of dependence on the natural resource were identified: price of natural resource, quantity of natural resource, availability of alternative suppliers, social forces, legislation, switching costs and geopolitical risk.

In terms of the second question, this work contributes to extant literature by showing that the importance of a resource will lead to buffering strategies. When the number of suppliers is limited and when companies face difficulties in owning, accessing, or using scarce natural resources, buffering strategies and bridging strategies are adopted.

5.2 Research implications

This research contributes to the current literature in multiple ways. First, it employs a RDT lens with the aim of gaining an in-depth understanding via theoretical elaboration and exploration of natural resource dependencies and associated supply chain strategies in the manufacturing sector. This is one of the first research studies that applies an RDT perspective in this context. Previous studies do not include an empirically grounded theoretical conceptual framework except Bell *et al.* (2013).

Most papers do not take into consideration the contingent factors that can change the natural resource dependence level and thus the adoption of supply chain strategies for managing dependencies (Esper and Crook, 2014). Prior studies (Paulraj and Chen, 2007; Ellis *et al.*, 2010) focused on a few resource dependence constructs such as limited number of suppliers and, overall, there is a lack of attention to natural resource issues (George *et al.*, 2015).

Regarding the second contigent factor of supplier substitutability, the findings are partially in line with RDT theory and previous studies (e.g. Bode *et al.*, 2011; Meznar and Nigh, 1995; Su *et al.*, 2014). It is supported that low substitutability of suppliers is the key driver of bridging strategies while our findings indicate that buffering strategies are used as well. This shows that bridging strategies alone are not an effective approach as they do not remove the basic source of vulnerability. RDT was further examined in the context of NRS by determining all important types of contingency factors namely the price of the natural resource, quantity of natural resource, availability of alternative suppliers for the natural resource, switching costs associated with switching suppliers providing the natural resource, legislation, geopolitical risk, and social forces that can hinder the ownership of the natural resource and the ability to access and use the natural resource.

This research also draws attention to the strategies available for managing the issue of NRS, establishing possible credible links between natural resource dependence level and supply chain strategies. Past studies (Bode *et al.,* 2011; Bell *et al.*, 2012; Bell *et al.*, 2013; Mishra *et al.*, 2016; Ro *et al.*, 2016) identified several strategies, but have either treated them in isolation or have fallen short in identifying when to employ each strategy. RDT was further elaborated in the context of NRS by developing a set of supply chain strategies to minimise the natural resource dependence level.

Third, this research is one of the first empirical studies addressing NRS and their impact on manufacturing supply chains. The manufacturing sector is a resource intensive sector as resources account for at least 40% of the manufacturer's cost but one that has not received attention on how resources might affect the operational challenges for risk management (EEF, 2014). The empirical evidence collected in different manufacturing subsectors indicates that the conceptual framework can be applied to other sectors as well.

5.3 Managerial and Policy implications

This research offers a systemic perspective towards multiple natural resources providing a useful framework, as a starting point for manufacturing firms, that want to determine a successful supply chain strategy for overcoming NRS. Supply chain and purchasing managers need to evaluate the implications of NRS risk and, when appropriate, mitigate this risk using specific strategies. This research increases managerial understanding of the advantages and disadvantages of those strategies. Another practical implication is the early involvement in the product design process that was highlighted by AutoCo_1 and the supplier of wiring connectors. This can ensure that important issues such as regulation, cost and resource or suppliers' availability are considered by product designers early enough informing their decisions regarding the usage of specific resources.

The cases highlight a lack of transparency for certain materials in the automotive industry such as REE as their suppliers do not transfer information beyond first-tier suppliers. Managers could perhaps facilitate information exchanges by not only identifying and quantifying the respective benefits, but by also including these in their existing reward sharing mechanisms.

Different antecedents such as legislation affect the appropriateness of various strategies. Buffering strategies are used as a defense strategy to alter and overcome the given contingent factor and to minimise resource usage and the purchasing cost. Managers should gather information and collaborate closely with suppliers in order to find where scarce natural resources appear in their products and operations. This is in line with Matopoulos *et al.* (2015) who suggested the "resource awareness" requirements of supply chains. This study shows that when it comes to resource scarcity implications, suppliers could be playing a more proactive role influencing the smooth functioning of the supply chain.

Regarding policy implications, there seems to be an effort to set standards on how to deal with the scarcity risks for some resources (see for example, EU's Raw Materials Initiative, National Strategic and Critical Minerals Production Act of 2013, H.R. 761). This perhaps reflects policy makers' worries about the impact of resource scarcity on their country's growth and the ability of manufacturing companies to compete in global markets. However, these initiatives are still quite abstract lacking a more concrete set of actions and guidelines.

It also appears that legislation sets different targets for different natural resources. For example, the end-of-life vehicle directive led automotive companies to recycling of materials in vehicles, however there is no legislation that incentivises companies to recycle water.

Some legislation prevents companies from applying other legislation. There is no concrete directive that substantially influences and gives incentives to manufacturing companies to design product for easy reuse or recycling.

Overall, this research provides a unique framework with more consistent strategies that can assist policy makers in assessing scarcity issues, thus informing their decisions. Policy makers could use the empirical findings of the study for better understanding and managing the challenges of a resource constrained world. They must be more aware of the available supply chain NRS strategies and its antecedents in order to provide concrete targets and indicators to manufacturing companies for improving the efficiency of resource usage. For example, recycling can enable a more resource efficient economy giving countries or continents such as Europe, a competitive advantage and minimise its dependency on foreign sources. Recycling opportunities are not used to their full potential.

The United Nations Environment Program (2011) study found that less than 1% of REEs are recycled. Low recycling rates mean a missed economic opportunity, for example, non-recycling of copper means an annual loss of $52 billion (MacAurthur, 2012). Scarcity issues must be integrated into policies and policy makers have to monitor how this is progressing.

5.4 Limitations and future research

The relatively varied set of cases suggests a possibility for some generalisation of our findings to all manufacturing industries. However, the case method has limitations in terms of external validity; hence, further quantitative testing of the conceptual model and of the propositions developed is recommended. This research focuses on large multinational companies. Based on RDT, size is one important organisational factor that has implications on firms' behaviour in response to changes in market environments. Smaller companies are not explored in this study and future research would be beneficial to identify similarities and differences between large and small companies and the preferred strategies in relation to firm size.

Future research needs to examine response strategies more closely especially their impact on organisational performance. For example, relational mechanisms may lead to an increase of a buyer's dependence on the supplier, but others such as hierarchy mechanisms might not. In this research, the information that is transferred in the buyer–supplier relationship was not addressed. Future research could determine the relationship between the content of the exchanged information and the risk of NRS. Finally, this paper focuses mainly on non-renewable resources such as REEs and energy but also on water which is a renewable resource. The findings may not be transferable to other natural resources such as timber and to other industries such as, inter alia, the chemical and electronics industry. To get a broader picture of the NRS, other natural resources and industries should be analysed, and general conclusion should be made about their overall scarcity impact on manufacturing companies.

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Table 1: Profile of companies in the case studies

Company Name	Industry	Number of Employees (approximately)	Turnover (approximately)	Interviewees / Key Informants
AutoCo_1	Automotive: One of the largest US multinational OEMs.	181,000	£94 billion	2 Senior Purchasing Managers
AutoCo_2	Automotive: UK manufacturer of automotive Bodyin-White products and services.	650	£66 million	Logistics Manager, Purchasing Manager, Purchasing and Logistics Director
AutoCo_3	Automotive: UK multinational OEM.	30,000	£19 billion	Sustainability Manager, Supply Chain Manager, Purchasing Corporate Social Responsibility Manager, Product Environment Manager, Product Stewardship Manager, Materials Engineer, Group Leader in Sustainable aluminium Strategies, Materials Engineering Manager
AutoCo_4	Automotive: UK multinational seat manufacturer for a variety of applications.	300	£66 million	Purchasing Director, Environmental Manager, Logistics Manager
AlumCo_5	Aluminium: Norwegian multinational manufacturer of extruded aluminium	23,500	£2.5 billion	Director of Global Strategic Sourcing , Vice President of Corporate Social Responsibility Manager, Vice President of Strategic Sourcing
AlumCo_6	Aluminium: US multinational manufacturer of industrial aluminium	11,000	£7 billion	Environmental Manager , Plant Manager, Senior Purchasing Manager

Table 2: Natural resources related to each company

Natural Resources Examined	Company Name(s)
Energy ,Water, Rare Earth Elements, aluminium	AutoCo_1, AutoCo_2, AutoCo_3

Energy ,Water, aluminium	AutoCo_4, AlumCo_5, AlumCo_6

Table 3: Buffering and Bridging Supply Chain NRS Strategies across the 6 Cases

Aggregate dimension	Second-order themes (First-order themes)	Auto Co_1	Auto Co_2	Auto Co_3	Auto Co_4	Alum Co_5	Alum Co_6
Buffering Strategies	Product and Process (re-)configuration						
	Recycling						
	Water	✓	✓	✓	✓	✓	✓
	Aluminium	✓	✓	✓		✓	✓
	Energy	✓			✓		
	Substitution						
	REEs	✓		✓			
	Energy	✓	✓	✓	✓	✓	✓
	New technologies to minimise the usage of resources						
	Energy	✓	✓	✓	✓	✓	✓
	Water	✓	✓	✓	✓	✓	✓
	Aluminium	✓	✓	✓		✓	✓
	REEs	✓		✓			
	Supply chain (re-)configuration						
	Close loop supply chain (water, aluminium and REEs)	✓	✓	✓	✓	✓	✓
	Safety stock			✓		✓	

Bridging Strategies	Transactional Mechanisms						
	Water	✓	✓	✓	✓	✓	✓
	Energy	✓	✓	✓	✓	✓	✓
	Relational Mechanisms						
	Aluminium	✓	✓	✓	✓	✓	✓
	Hierarchy Mechanisms						
	Aluminium					✓	

Table 4: Representative Quotations for the Impact of Natural Resource Dependence Level on Supply Chain NRS Strategies

Representative quotations	Causality	Company	Proposition Support
" Aluminium is an expensive material, the more we can recycle it the better we will be from a cost base" *"Aluminium is obviously high value scrap no one really recycle steel scrap"*	Purchasing importance leads to recycling.	AlumCo_6 AutoC0_2	P1a (Importance of the scarce natural resource and buffering strategies)
"We are going to manufacture cars in Saudi Arabia. The driver for that is because the Saudis have a huge quantity of aluminium bauxite"	Criticality leads to supply chain (re-)configuration .	AutoCo_3	

"By working closely with our top customers, we have minimised the usage of aluminium…So when you first design a blank it might be the sise of this piece paper but once you try to make a part out of it you may decide it doesn't need to be actually this big …so before you go into full production you make the blank smaller"	The low number of alternative suppliers leads to product and process (re-)configuration .	AutoCo_2	P2a (Supplier substitutability and buffering strategies)
" "We have identified the largest suppliers the strategic suppliers and *most of our metals come from the long term strategic suppliers"* *"So if we change the supplier, the testing has to be redone. So we can't just switch. "so "We have with our production suppliers … few long term agreements"*	The low number of alternative suppliers leads to relational mechanisms.	AlumCo_5 AutoCo_4 AutoCo_1	P2b (Supplier substitutability and bridging strategies)
"You have to prove to the government that you are proactively reducing your impact on the environment." Thus they have "a process for low energy lighting across the factory and the offices" *"We also comply with the EU ETS European Emission Trading Scheme so we are allocated an amount of carbon that we can use, obviously natural gas"*	Legislation leads to new technologies and substitution.	AutoCo_4 AlumCo_6	P3a (Discretion of the scarce natural resource and buffering strategies)
"In the future there are likely to be severe restrictions and this not only depends on the acquisition mining availability but also it depends on political objectives. We are starting recognise the issue … where the materials coming from, is from China, Russia so these countries are politically sensitive areas on specific materials "so "Create a close loop system (by close collaborating with our aluminium supplier) where basically aluminium is coming from the production line"	Geopolitical risk leads to: -Supply chain (re-)configuration (recycling) -Relational mechanisms	AutoCo_3	P3b (Discretion of the scarce natural resource and bridging strategies)

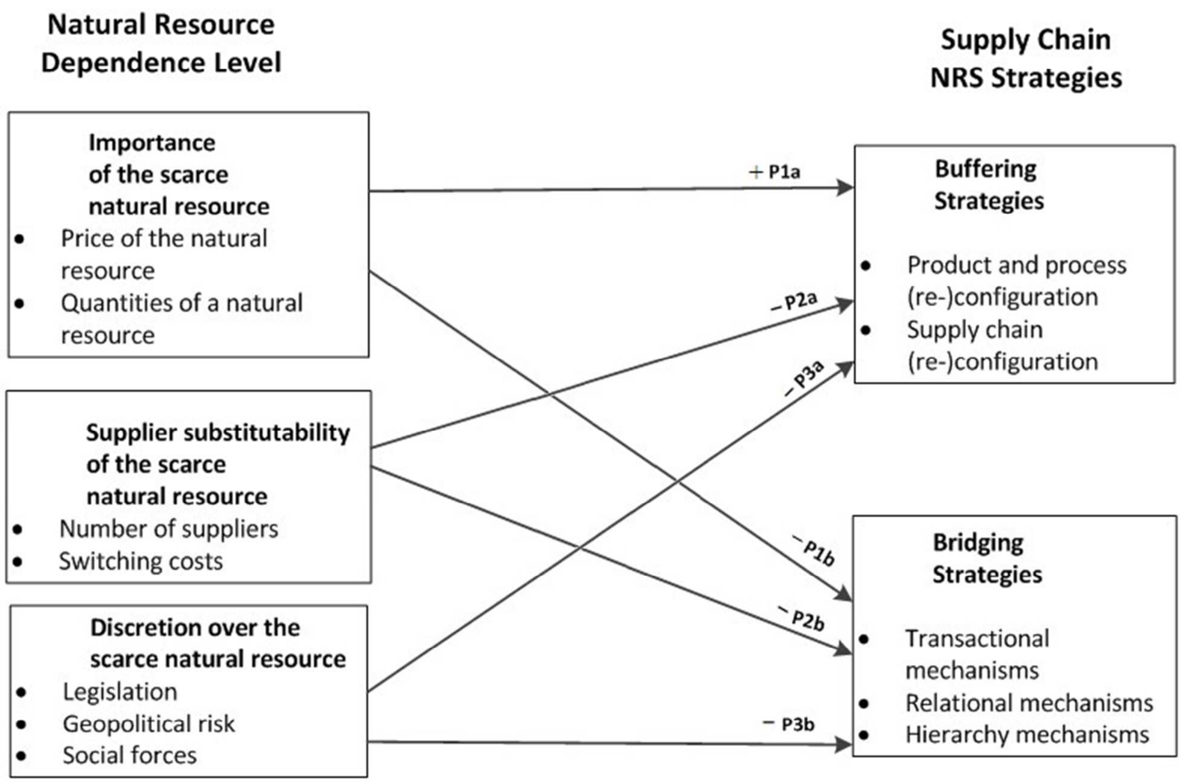

Figure 1: The Conceptual Framework and Propositions

Appendix A
The interview guide

General Respondent Information

- Please describe what do you do in your job?
- How long have you been working for [your company]?

Natural Resource Dependence Level and Supply chain NRS strategies

- What do you see as the main pressures and reasons to manage the issue of natural resource scarcity effectively in your firm that could affect your supply chain and product portfolio?
- Are those pressures mentioned above being matched with appropriate remedial measures?
- Please concentrate on a recent natural resource scarcity issue (during the last five years), can you describe the main reason(s) of the scarcity? how your production and operation have been adjusted to this change?
- What types of supply contract do you generally have with your suppliers that provide you with scarce natural resources?

Outcomes

- What more can you do to handle the issue of natural resource scarcity? Are you planning to do any of these?

Appendix B
Within-case and cross-case analysis approach

The transcripts were examined for each case to identify first-order codes and to be illustrated with simple descriptive phrases or quotes related to the research questions. Upon concluding this first stage of analysis, a detailed case narrative was written that describes the supply chain NRS strategies employed or new strategies being introduced, and its antecedents i.e. the natural resource dependence level. Specifically for the AutoCo_1 transcripts, the firstorder codes derived included the price of the natural resource, the number of suppliers and legislation (see Table below, second column).

The second stage aimed at linking themes to contexts, to consequences, to patterns of interaction and to causes (Corbin and Strauss, 2008). The first-order themes that share similar meanings were compared with the literature and clustered into higher-order themes, i.e. the second-order themes. For example, legislation is a factor that hinders the discretion over the scarce natural resource (see Table B1 below, second column). Finally, all first and second level code categories were interatively re-categorised to higher level categories. At this point, the analysis was organised around two main axes: natural resource dependence level and supply chain NRS strategies. The aggregate dimension in Table B1 below (fourth column) is natural resource dependence level. The process was applied for the supply chain NRS strategies of AutoCo_1 and was followed for all 6 cases.

Table B1: Themes and Quotations for the Natural Resource Dependence Level dimension (AutoCo_1)

	First-order themes	Second-order themes	Aggregate dimension
"The reason that led us to take some specific strategies was cost….By referring to cost we mean price of raw materials." (Purchasing Manager B) *"If you are missing a nut that you need to make a car that box of thousand hypo nuts loses you thousand dollars that has overhead profit costing 10 million dollars. So that box of nuts is worth ten million dollars if you don't have them when you need them."* (Purchasing Manager A)	Price of the natural resource	Importance of the scarce natural resource	Natural Resource Dependence Level
"We don't have many suppliers." (Purchasing Manager B) *"Usually we have a single source supplier"* (Purchasing Manager A)	Number of suppliers	Supplier substitutability of the scarce natural resource	
"There is a legal responsibility to recycle cars." (Purchasing Manager B) *"The legislation drives car makers"* (Purchasing Manager A)	Legislation	Discretion over the scarce natural resource	

The themes continued to emerge until a clear understanding of the relationships among categories was made and until additional interview transcripts and analyses failed to show new relationships. At the end, 20 first-order themes resulted and were grouped into 8 second-order themes developed deductively based on theory; further categorisation of these second-order themes resulted in the identification of 3 aggregated dimensions:

1) Natural resource dependence level (second-order themes: importance of the scarce natural resource, supplier substitutability of the scarce natural resource, discretion over the scarce natural resource).
2) Buffering strategies (second-order themes: product and process(re-) configuration, supply chain (re-) configuration) and,
3) Bridging strategies (second-order themes: relational mechanisms, transactional mechanisms, hierarchy mechanisms).

The two figures below depict the major themes and their relationships (see Figures B1 and B2). The identified themes provide a basis for building a data structure which is a pivotal step as data can be configured into a sensible visual aid and "it also provides a graphic representation of the progression from raw data to terms and themes in conducting the analyses — a key component of demonstrating rigor in qualitative research" (Gioia *et al.*, 2013, p.20). By integrating the themes and dimensions, the relationships among the emergent concepts become apparent. The relationships between the secord order themes of the three aggregate dimensions relationships (see Figures B1 and B2) and their consequences are explored in more depth in the sub-sections 4.2, 4.3 and 4.4. More importantly, each of these Figures has contributed to the subsequent formation of Figure 1.

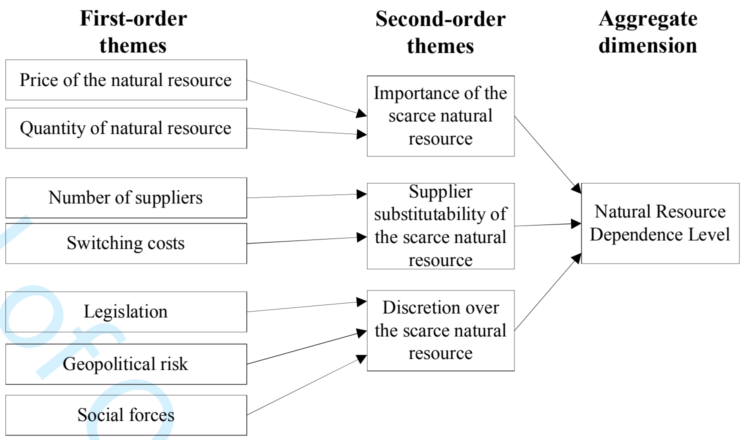

Figure B1: Data structure of Natural Resource Dependence Level

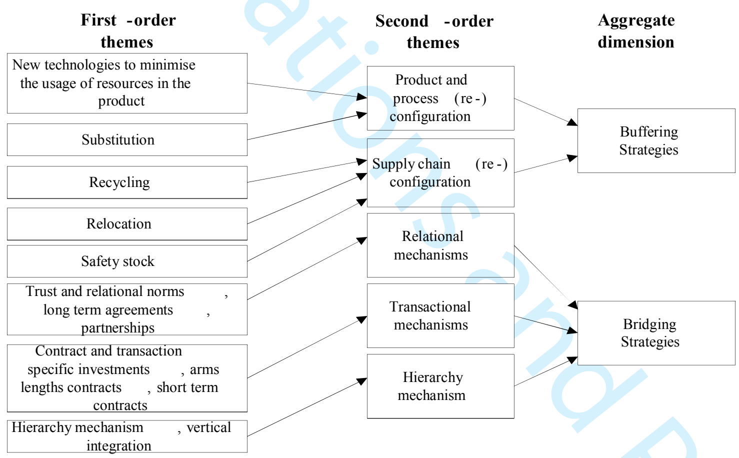

Figure B2: Data structure of Buffering and Bridging Supply Chain NRS Strategies