

# **Innovation in natural resource based industries: A pathway to development? Introduction to special issue**

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## *Abstract*

Despite growing academic attention to the relationship between economic development and natural resources in social sciences, there has apparently been rather limited activity in the field of Innovation Studies. This is problematic given the centrality of innovation and technological change for growth and development. Against this background, this introductory article aims to make four contributions. First, to assess the extent to which Innovation Studies has analysed the link between natural resources and development. Second, based on recent studies of innovation in natural resource based industries (NRBIs) we elaborate on and articulate an innovation and industry perspective on the relationship between natural resources and development. In this, we foreground the particularities of innovation in NRBIs. Third, we explore policy implications of the specificities of innovation in NRBIs. It matters greatly for design and choice of policy instruments in support of innovation and development whether and how innovation in NRBIs differ from innovation in other industries. Lastly, we introduce the papers constituting this special issue and propose avenues for further research.

Keywords: Natural resources; Innovation; Innovation Studies; Development; Innovation policy; sustainability

# 1 Introduction

Natural resources are indispensable for the functioning of human societies and economies. They are the primary inputs to most production processes and supply much energy for transport, light and heat around the world. Natural resources are unevenly distributed across countries and are therefore extensively traded and can strongly influence a country's industrial specialization (WTO, 2010). Management of natural resources has moreover a huge bearing on industrial development in areas of resource production as well as the global scope for moving towards sustainability.

The relationship between economic development and abundance of natural resources has received extensive and growing academic and policy interest (cf. Figure A1). Academic research however, dominated by the disciplines of Economics and the related fields of Management and Business (cf. Table A2) has tended to pivot around the notion of the "resource curse" (cf. Table A3); a notion that emphasises governance problems related to corruption and different aspects of monetary policy (Frankel, 2012; Ross, 2014; Torres, Afonso, & Soares, 2013). Surprisingly little attention has been paid to perspectives related to innovation and industry dynamics associated to natural resources (cf. Section 2). This is problematic given the centrality of innovation and technological change for growth and development (Abramovitz, 1986; Lundvall, Joseph, Chaminade, & Vang, 2009; Nelson, 2008; Solow, 1957). It is the aim of this introduction and the papers included in this special issue to articulate and contribute to an innovation and industry perspective on the relationship between natural resources and development as well as taking stock of the academic field.

There have been different reactions to the dominance of the resource curse thinking. David and Wright (1997), for instance, were pioneers in proposing that natural resource based development is realized through the generation and use of new and relevant knowledge, and that it is possible for natural resource based industries (NRBIs, cf. Text Box 1) to lead economic development for extended periods of time. Moreover, several recent studies have demonstrated that NRBIs can be sources of important innovations and technological opportunities for productivity improvements in resource production but also for stimulating innovation in other parts of the economy. These studies include high-income economies such as the US, Norway and Australia (David & Wright, 1997; Smith, 2007; Ville & Wicken, 2012), middle income developing countries such as Chile, Argentina and Brazil (Dantas, Marín, Figueiredo, & Bravo-Ortega, 2013; Iizuka & Katz, 2010; Marin, Stubrin, & da Silva Jr., 2015; Pérez, 2010) and low-income countries in Sub-Saharan Africa (Morris, Kaplinsky, & Kaplan, 2012a; Teka, 2011; UNIDO, 2012). Combined, these studies constitute the beginning of a new wave of thinking about NRBIs in relation to innovation and industry dynamics – and about the possibilities for natural resource based development. This branch of research does not reject all insights from the resource curse debate. Sound management of macroeconomic fundamentals, careful exchange rate policy, institutional quality and 'good governance' are important, although in our view insufficient, factors in a development strategy. In addition, it is acknowledged that NRBIs historically have mostly been enclave industries in developing countries. Nonetheless, this budding area of research suggests that such vices need not be inherent properties of NRBIs, but rather symptoms of other

shortcomings. In this light, we understand that the main question is not whether, but how innovation and industry dynamics can be managed to deliver development in natural resources. We draw on the evolutionary approach to innovation and industries studies that underpins this recent research to define natural resource based development as a process of structural change where the expansion of NRBI is associated with processes of innovation and competence building within (in producers), around (in suppliers and users), and beyond (knowledge spillovers via diversification) natural resource production to deliver long-term benefits for the national economy (Andersen et al., 2015).

**Text Box 1: Natural resource based industries**

Natural resources are defined as factors of production provided by nature. They belong to what is traditionally referred to as the primary sector of the economy, which also encompasses the secondary (manufacturing) and tertiary (service) sectors. We refer to the industries in the primary sector as 'natural resource based industries' (NRBIs) and we refer to economies whose industrial structure is dominated by NRBIs as 'natural resource based economies' (NRBEs).

As a consequence of unfolding megatrends in the global economy, innovation in NRBIs has apparently intensified in recent years. This augmented innovation activity, which is reflected in many of the studies mentioned above, naturally generates a heightened relevance of and attention to an innovation and industry perspective on natural resources; particularly in developing countries. Here we review the four most important of these trends (Marín, Navas-Aleman, & Perez, 2015). First, recent decades have experienced an acceleration of growth in the demand for energy, food and raw materials to the point of straining the limits of resources (Alexandratos & Bruinsma, 2012). This increase in the volume of demand has provided opportunities to increase productivity and production via innovation. Second, challenging the commodity notion of natural resources, worldwide demand for less standardised and higher quality goods is expanding (i.e. organic wines, more aromatic lavender, tomatoes of different colours, high-quality and sustainable produced lumber, etc.). The large varieties of natural resource products that are offered today for culinary, cosmetics (e.g. Amazonia essences), health and ecological purposes enhance the possibilities of differentiation related to natural resources and thus innovation. Third, a major change in recent decades has been the emergence of new technologies such as biotechnology and nanotechnology, which are multiplying the possibilities of differentiation and innovation in activities related to NRBIs. Natural resource producers are incorporating these new technologies in the production of natural resources and this is questioning the 'low-tech' notion of NRBIs, as well as forming and deepening of linkages towards other industries creating new opportunities for diversification. Fourth, Multi-National Corporations (MNCs) are increasingly outsourcing non-core functions locally and, due to new competition and resource nationalism, applying Corporate Social Responsibility measures to enhance transparency and engagement with local communities. Combined, these factors can create new opportunities for domestic small and medium sized firms if they can respond with innovation and upgrading (Morris et al., 2012a; Narula, 2018). These trends point to an increasing role for innovation activity in natural resource based industries and enhanced scope for further opportunities.

Against this background, this introductory article aims to address three interrelated issues. First, to assess the extent to which the field of Innovation Studies has analysed the link between natural resources and development. Second, based on recent studies of innovation in NRBIs to further elaborate on and articulate an innovation and industry perspective on the relationship between natural resources and development. This pivots around the question of whether, and if so how, innovation in NRBIs differs in some qualitative sense from innovation in other parts of the economy. Indeed, it is the working hypothesis of this special issue that innovation in NRBIs does differ. Even though we have several indications that this is the case, the scarcity of studies analysing innovation in NRBIs implies that we need more and better studies. Third, to explore policy implications of the specificities of innovation in NRBIs. It matters greatly for design and choice of policy instruments in support of innovation and development whether and how innovation in NRBIs differ; particularly for developing countries with rich natural resource endowments. In the following, we attend to each of these points.

We proceed by reviewing the Innovation Studies field for analyses of NRBIs via a bibliometric exercise and an interpretation of the literature. In section three, we take stock of what we actually do know about innovation in NRBIs. Then, we introduce the issues and papers of the special issue and connect them to different aspects of the introductory review before ending by outlining some issues worthy of further research.

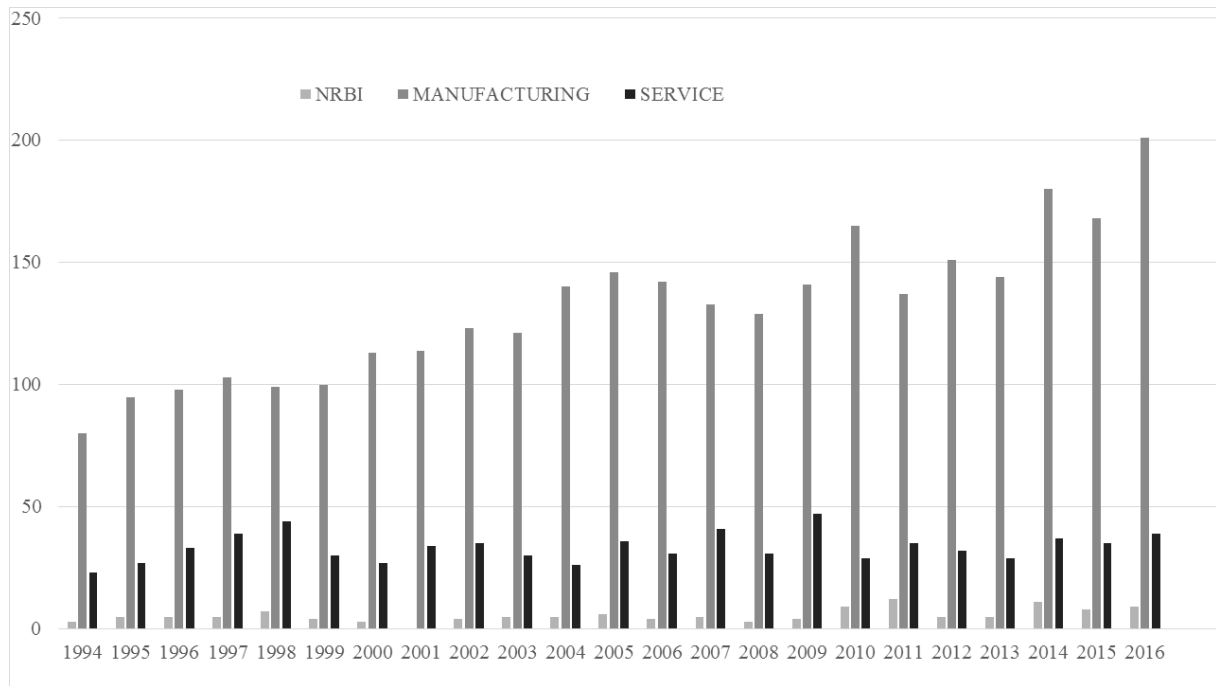
## **2 Innovation Studies and natural resources**

Innovation researchers have tended to concentrate on analysing innovation in manufacturing and more recently also service industries thereby creating a bias in the empirical coverage of the field (Martin, 2016), cf. Figure 1. That assertion is confirmed by our bibliometric analysis which shows that in the period 1994 until today, manufacturing accounted for 3289 of 16,085 Innovation Studies articles (about 20%), while the service sector counts 832 articles (around 5%). In comparison, NRBIs have been analysed in 137 studies (0.85%) of which only 12 articles take a conceptual interest in natural resources and innovation.<sup>1</sup>

It is therefore not surprising that Innovation Studies operate with a manufacturing-based perception of the mechanisms underlying industrial development. This is aligned with early structuralist's views which saw little opportunities for learning and innovation, and linkages in association with NRBIs, and that attributed all potential for development to manufacturing. (Hirschman, 1958; Prebisch, 1950; Singer, 1975). It is also aligned with historical studies on catching-up that suggest that low-income countries had to emulate the industrial paths taken by high-income countries to develop (Gerschenkron, 1962; List, 1841). These studies inspired a branch of research on technology gaps, catching-up, innovation, and latecomer advantages contemplating productivity developments in post-World War 2 Europe and USA and subsequently in the 'East Asian Tiger' economies, and emphasise that for catching-up to happen countries should foster development of the more rapidly-growing and technologically progressive industries of the day (Fagerberg & Godinho, 2005), by that time manufacturing.

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<sup>1</sup> For more information and methods, see appendix.



**Figure 1: Number of yearly articles within Innovation Studies research on NRBI, manufacturing and service industries.<sup>2</sup>**

The most recent of these experiences of catching-up is that of the East Asian countries. The rise of the ‘East Asian Tiger’ economies have been portrayed through the metaphor of a flock of flying geese with Japan as the lead goose followed by first tiers (Korea, Taiwan, Singapore, Hong Kong) and second tiers (Malaysia, Thailand, Indonesia, and even China) birds. Similarly to the catching-up story, the flying geese model conveys a linear stages-model of dynamic comparative advantage which depends on innovation in the lead country and absorptive capacity in follower countries (Kasahara, 2004). Even though the model has been widely criticized for overlooking central aspects of East Asian catch-up (Hobday, 1995), it has become very influential and is widely understood as a generic model for catch-up and innovation (Lin, 2012; Mathews, 2006). It posits that catching-up is roughly a three-stage process. It begins with the copy, replication, and reverse engineering of existing technologies developed by lead firms in high-income countries. Subsequently firms in low-income countries move on to creative imitation (i.e. making minor improvements to the original technology), and lastly they become innovators of novel items and reach the global knowledge frontier (Amsden & Tschang, 2003; Hobday, Rush, & Bessant, 2004; Kim, 1991; Lall, 1987; Mathews, 2002).

Transfer of technology from the leader to follower countries is a central mechanism of this model. Catching-up firms and countries access this knowledge through a range of different mechanisms such as trade, inward and outward FDI, user-producer relations, joint ventures, mergers, and R&D collaborations (Archibugi & Iammarino, 2002). In consequence, MNCs are—and increasingly so—seen as central conveyors of industrial knowledge from one

<sup>2</sup> For methods, see appendix.

national economy to another (Carlsson, 2006; Narula & Zanfei, 2005). A basic assumption behind this thinking is that (Narula, 2003, p. 5):

*“...there is a convergence between countries in the kinds of knowledge being used”*

Therefore, the relevant technologies for industrial advance are the same globally. Partly as a consequence, studies of catching-up and innovation have predominantly focussed on analysing the institutional arrangements that enable access to, absorption and efficient use of key dynamic technologies (Nelson, 2004).

The view that a set of universal key technologies and industries drive development across countries can be accounted for by the fact that catching-up in East Asia was mainly based on manufacturing industries such as shipbuilding, textiles, cars, and consumer electronics (Mathews, 2006). Such industries can produce homogeneous output given the same input factors and production process regardless of geographical location. This feature of manufacturing industries implies that the technology involved predominantly is generic. Indeed, it is often emphasized as a latecomer advantage that technology and “roadmaps” for catching-up already exist (Mathews, 2006). The latter perspective fits rather well with the notion that shifting techno-economic paradigms—that each has a set of key technologies at its core—drive long-run growth, and whose potential can only be exploited with new and appropriate institutions (Freeman & Louçã, 2001; Perez, 1985). As a consequence, the main tasks for policy in fostering industrial advance in manufacturing industries include to access, absorb, and apply—often foreign—generic technology through different phases of replication, creative imitation, and lastly new-to-the-world innovation.

If one’s conceptual starting point is that a limited set of key industries are central for industrial development in each era, it is understandable that researchers focus on the institutional and social arrangements required for reaping the benefits of these industries. However, it is also apparent that the dominance of such thinking—although tremendously valuable—can generate a blind spot towards innovation in NRBI and little theorizing about innovation and development in relation to natural resources. As a reflection of the conceptual bias in Innovation Studies, there has been proportionally little interest in empirically analysing NRBI wherefore we currently know relatively little about innovation and industry dynamics in this type of industries.

### **3 What do we know about innovation in NRBI?**

In this section, we discuss four main issues characterising innovation in NRBI. They are derived from the few studies that have explored natural resources and innovation.

#### **3.1 A dynamic perspective on natural resources**

Following an evolutionary perspective on industrial development, the importance of taking a dynamic view on natural resources cannot be overestimated. Such a view implies that natural resources are not static or absolutely finite but rather expand and contract in response to changes in our common stock of knowledge and our valuations (or scarcity) of various resources (Rosenberg, 1976). In this regard, it is useful to distinguish between nature and natural resources. Nature is the topic of natural science and concerned with the physical

universe which we, for our purposes, can think of a finite and static. Social science, however, is concerned with natural resources which we can understand as that ever-changing portion of nature that is known to man and affects his existence (Zimmermann, 1972). Many of the theoretical arguments critical of natural resources implicitly presume that natural resources are not an outcome of production processes but are extracted, with only minimal effort. Humphreys, Sachs and Stiglitz (2007, p. 4) for example argue that:

*“...unlike other sources of wealth, natural resource wealth does not need to be produced. It simply needs to be extracted. Since it is not a result of a production process, the generation of natural resource wealth can occur quite independently of other economic processes that take place in a country; it is in a number of ways, enclaved... without major linkages to other industrial sectors”.*

It follows that innovation is irrelevant. This line of thinking is however flawed. It rests on the assumption that nature, which is freely available, equals natural resources (Andersen, 2012). In the interface between nature and natural resources, there are ongoing processes of resource creation, obsolescing and extension, which are enabled by innovation. This explains how resource deposits continue to grow and how new resources are discovered as we learn. The main implication, however, is that the production of natural resources requires innovative inputs from services and manufacturing activities of varying knowledge sophistication as well as support from science and technology development. The complementarity of these distributed factors in understanding the dynamics of natural resources to some extent calls for a systemic approach to grasp these processes (Andersen & Johnson, 2014). The presented perspective opens for the possibility that NRBI indeed can be drivers of skill creation, job growth, innovation and industrial development with beneficial impacts on the wider economy.

### **3.2 Innovation and the importance of suppliers and users**

First and foremost, it is well known that innovation does take place in NRBI, and we know that the properties of the supplier industry and professional users, and how these interact with producers of natural resources and knowledge organizations, is crucial for innovation in NRBI (see e.g. Adejuwon, 2017; Adewuyi & Oyejide, 2012; Andersen, 2015; Bloch & Owusu, 2012; Figueiredo & Piana, 2016; Kaplan, 2012; Leeuw, 2012; Lydall, 2009; Morris, Kaplinsky, & Kaplan, 2012b; Smith, 2007; Teka, 2011; Torres-Fuchslocher, 2010; UNIDO, 2012; Ville & Wicken, 2012). Inter-industry linkages are thus seemingly relatively more important for innovation in NRBI. Pavitt (1984), for instance, classified NRBI as dominated by a supplier driven mode of innovations. This does not mean however that all innovation happens in the supplier industries, independent of natural resource producers. The demands, the quality of the demands and the way in which these are communicated play a crucial role to incentivise and shape innovation in supplier industries. This is even more so if we consider that in many cases natural resource producers are large companies and suppliers small and medium firms. The notion of user-producer interactive learning captures the essence of such linkages (Lundvall, 1985). Although a conceptual link to NRBI has not been established yet, others have discussed a similar phenomenon at the industry level as the mutual dependency between recipient and enabling industries (Robertson, Pol, & Carroll, 2003); something which is also discussed in the literature on innovation in low-tech industries (Tunzelmann & Acha,

2005). What seems crucial therefore is to understand the linkages between natural resource producers demanding knowledge, and the industries supplying equipment's and solutions, how these work, and which are the ones favouring or limiting innovation within these linkages.

A related challenge is that in situations where MNCs dominate a NRBI in a developing country, there will often be a significant knowledge gap between MNCs and local suppliers. Such conditions can lead to 'enclave type' industries where both upstream and downstream activities are located outside the country. The developing country thus not only loses the chance to capture value added but also, and more importantly, its prospects of developing an own supplier industry. In such cases local content policies combined with investments in specialized education, training, and research may provide a solution (Guimarães, 2012; Mendonça & Guilherme, 2013; Ovadia, 2014; Ranestad, 2017).

The presence of a dynamic supplier industry to the natural resource producers is important because the performance of each of them is mutually interdependent. Indeed, such a mutual dependency between producers and suppliers is often a central aspect of industrial development (Porter, 1990). In terms of generating societal value from natural resources, having a strong local supplier industry can be a larger source of employment and export income than the actual production of natural resources (see e.g. Ryggvik, 2013). Nurturing a local supplier industry is however even more important because of the learning, innovation, and competence building that take place in the process. The technology and competence base used to serve and improve natural resource production can over time become an important platform for diversification of the broader economy. For example, it often happens that technology suppliers to NRBI's build rather generic competences such as automation, ICT or chemical science which can be applied elsewhere (Kuramoto & Sagasti, 2006; Lorentzen, 2006). In Australia, for example, technology suppliers to the mining industry are heavily engaged in developing software systems (Smith, 2007). In Norway, the supplier industry to oil and gas has developed a range of technologies that have found application in for example the offshore wind industry (Mäkitie, Andersen, Hanson, Normann, & Thune, 2018; Steen & Hansen, 2014). The servicing company SMAR in the Brazilian sugarcane industry moved from simple equipment repair over automation of cane crushing to developing digital control systems to the US Navy (Andersen, 2011). In South Africa, mining technology suppliers developed a low-radiation, full body imaging device—to scan mine workers for stealing diamonds—for the diamond mining industry which was later applied in the medical industry (Mayer & Altman, 2005).

The prospects of long-term natural resource based development thus often hinges on both developing a local supplier industry as well as the continued upgrading and diversification of that competence base to facilitate industrial diversification.

### **3.3 *Embeddedness in the natural environment***

In contrast to the industries of the secondary and tertiary sectors, NRBI's are to a much larger extent immersed in a unique geological and ecological context (Rosenberg, 1976). Mokyr (1992, p. 296) for example argues that:



*“...in mining and agriculture, what worked in one place might not work elsewhere if the topographical, climatic, or soil conditions were different. The American reaper, for example, could not be applied to the British landscape. Fertilizing, drainage, irrigation, seed selection, animal breeding, the erection of fences and hedges—all were functions of local conditions and could not be made to work universally”.*

Following Andersen et al. (2015) we will refer to this feature as ‘natural resource knowledge idiosyncrasy’ (NKI). It has three important implications for our understanding of natural resource based development.

First, as a consequence of NKI, knowledge produced in a specific location might not always be useful to every other location. This feature of natural resources questions the conventional model of innovation and development in developing countries that conceptualizes it as a sequence that starts with the copy and replication and, finishes with innovation, cf. above. Recent research has suggested that to face “natural resource knowledge idiosyncrasy” some firms in developing countries have developed different pathways of technological upgrading to those followed by industry leaders from advanced countries. This was because, among other things, the first step—knowledge imitation—on the ladder of upgrading that worked well in manufacturing was not available. Figueiredo (2010), for instance, has shown how some Brazilian firms within the pulp and paper industry took advantage of the specific agro-ecological conditions of some areas of Brazil, which were favourable to the fast and efficient growth of eucalyptus, developing a completely new trajectory of pulp and paper production based on this tree, a trajectory that could not be imitated in the rest of the world by world-leading firms to produce pulp and paper. This process involved the development of capabilities to improve eucalyptus growing technologies, and by developing new processes of pulp and paper production out of eucalyptus, which were not previously available. Marin, Stubrin, and Van Zwanenberg (2014) and Marin and Stubrin (2015) have showed also how Argentinian firms, that began developing soy seeds adapted to local agro-ecological demands, first outcompeted MNCs in the domestic market and then were able to penetrate regional and global markets. This involved complex private and public partnerships and the development of local capabilities in diverse breeding technologies among others. These examples show that NKI is important, and might have positive and negative implications for innovation in NRBI. On the one hand, they are a barrier for the application of standardised solutions, and existing equipment developed elsewhere (as is the case for manufacturing industries). On the other hand, they provide an opportunity for entry for newcomers from developing countries, and for tracing different technological paths. Paradoxically, carving out an innovation and development path—including developing a local supplier industry—based on local geological and ecological specificities within NRBI may therefore constitute a more promising development plan than aiming to penetrate established and global manufacturing industries (Andersen & Wicken, 2016).

Second, the direct relationship between NRBI and the natural environment implies that industry expansion has a different spatial dimension than manufacturing industries. One implication of this is that NRBI must often operate on premises of social acceptance from the communities that their production activities affect. For example, institutions governing land and property rights may be particularly important for NRBI. More generally, nature is most

often seen as a public good, the expansion of NRBI may therefore easily be subject of various forms of controversies affecting their innovation dynamics. All this means, on the one hand, that NRBI are subject to multiple regulations, and institutions that are used to control exploitations and their effects. Institutions and regulations related to NRBI are therefore crucial for innovation. Countries interested in encouraging innovation, production and also preservation of natural resources and human development have to have in place the right regulations. Companies working with natural resources need to master and be able to face these regulations. On the other hand, it means that innovations should go beyond technological and scientific aspects. Companies and countries need to find ways to involve local communities, in a sustainable way to organise their activities. The conflicts related to natural resources are actually often a major barrier for the activity. These aspects suggest that natural resource based development should, to some extent, be socially inclusive (Arocena & Sutz, 2012; Johnson & Andersen, 2012; Johnson & Villumsen, 2017).

Third, NRBI are directly immersed in the local natural environment wherefore unsustainable use of nature can directly, and sometimes quite quickly, undermine the production of natural resources. That link is only indirect and very long-term for manufacturing industries. Some NRBI must therefore respect and understand the natural environment to greater extent than manufacturing industries (Iizuka & Katz, 2010). This often involves deep understanding of local geology, and ecological systems as well as their carrying capacity that, in turn, can inform environmental regulation and monitoring that can ensure a somewhat sustainable relationship with nature. If such considerations are taken lightly, both economic and ecological crises are likely to occur (Petrasic, 2015).

### ***3.4 Innovation Systems and policy for natural resource based development***

We indeed see the possibility of building on natural resources to create a pathway to development. But, to identify and formulate the adequate policies to deal with the developmental challenges related to natural resource based development, concepts and ideas from Innovation Studies need to be adapted to consider the specificities of NRBI.

Following our understanding of natural resource based development, policy should broadly stimulate innovation and competence building in five different areas: in natural resource producers, in related suppliers, users and supporting knowledge organizations, in support of diversification and knowledge spillover activity towards non-NRBI, in situ environmental management capacity, and management of social inclusion and distribution. Knowledge of local specificities is central for each of these activities.

In this section, we point to three important and more concrete issues that should be taken into account for policies related to natural resource based development.

First, ideas emerging from the innovation system literature are very relevant for natural resource based development, but they need to be adapted. Following a dynamic view on natural resources, the generation, diffusion, and use of knowledge via different forms of innovation is the pivotal issue in natural resource based development. Basic research, new scientific knowledge and new technological developments in several disciplines related to natural resources are crucial for innovation in NRBI. Multiple examples come from applications of

knowledge related to new materials, biotechnology, ICT, etc. The way in which natural resources producers and their suppliers connect with these knowledge bases, support new technological advances, access and shape new knowledge is important. Together with a set of distributed knowledge bases and institutions, producers, suppliers, and knowledge organizations as universities and research institutes make up an important innovation system, which is necessary to support innovation and productivity growth in NRBIs. Innovation system perspective seems thus very relevant to address this issue. Against this background, it is therefore meaningful to conceptualise the challenge of based natural resource based development as that of creating and supporting the institutions and organisations that generate, diffuse and use new knowledge and capabilities in the production and use of natural resources. In other words, we can think about this as building a natural resource innovation system.

Second, such innovation system however, must be locally anchored to address local specificity of knowledge needed to succeed. This implies addressing issues pertaining to the importance of in situ knowledge for appropriate design of technologies and products, the local challenges of environmental management, and the particular local issues regarding social inclusion. These are important challenges for developing countries that on many occasions due to the lack of development of their indigenous innovation systems are used to rely on foreign developed technologies and practices (Viotti, 2002).

Third, how to support innovation and competence building in the different areas mentioned above is sensible to context such as the changing nature of technologies and markets. Some of the policies that were important for development in countries that grew based on NRBI in the past might be relevant still, but not all of them will incorporate the urgent challenges of the present. An important aspect of the latter is creation of institutions and regulations that deal well with the new trends and challenges associated with natural resources, cf. introduction. For example, the management of natural resources and the new industries emerging in association with natural resources, such as biological, require new regulations and institutions. Governments need to develop public sector capabilities to introduce regulations and institutions that allow them to reap the benefits of these industries and that protect the sustainability of the activities. Developing countries usually face challenges for the development of such institutions. For instance, regulations related to Intellectual Property Rights (IPR) or to biosafety. Firms need also to develop capabilities to adapt to the changing and demanding regulations and institutions that characterise these industries. Accomplishing IPR and biosafety regulations, for example, can be important obstacles for these types of firms to compete and survive in this market. Governments seeking to support local natural resource-based companies also need to set up the right institutions and regulations (such as those related to IPR or market concentration) and need to support the creation of knowledge and skilled workers and supportive infrastructure that is more adequate to the domestic capabilities. But to do so they need to have a broad understanding of the industry and an informed view about its future prospects. A key question is thus; can developing countries develop the capacities and institutions to address these challenges in a creative manner, in the context of a global economy every time more “regulated” by international agreements? A related aspect is how firms and governments in developing countries engage with MNCs to

incentivise and ensure local linkages and innovation, and in particular the development of in situ knowledge rather than import of global innovations that might be inappropriate for local conditions.

## 4 Issues and papers in this special issue

The papers included in this special issue make a contribution to improve our understanding of the nature of innovation in Natural resources and related industries, how this takes place and should be managed.

One important issue addressed by some of the papers here is the *innovative and technological dynamism of NRBI*. The evidence of some of the papers here confirm that NRBI can be technologically dynamic, generate significant innovations and linkages with other sectors. For instance, the important role of innovation in linkages between natural resource producers and their suppliers is illustrated by how knowledge intensive service firms (KIB) enable diversification. Particularly, this is happening increasingly in association with advances in the knowledge bases related to NRBI, such as the biological, which is advancing fast and affecting possibilities for innovation in NRBI. Countries like the Latin American ones, analysed in several paper in this special issue, are in particular the context of this dynamism which stands in stark contrast to the historical exploitation of natural resources. This is a crucially important issue since to the extent that NRBI are conceptualised as less dynamic, they receive little attention from the point of view of innovation policy, and this might delay possibilities of development related to natural resources, which, as suggested in this article, are dependent on innovation, new knowledge creation, and supporting institutions.

Another important issue that emerges from some of the papers analysed here relates to the opportunities and challenges associated to the local specificity of innovations—*natural resource knowledge idiosyncrasy*—required to efficiently produce natural resources. The evidence in this special issue suggests, as previous studies have done so, that localised requirements generate an opportunity for local innovations and new entrants from emerging countries. Interestingly, it also suggests that these localised innovations are not always local adaptations of global innovations developed elsewhere. In some cases, as in the case of seeds in Latin America, these local innovations have been developed with a paradigm and proposing a technological trajectory, which significantly differ from that developed by global firms; with a different technological approach, knowledge, by different kind of actors, different institutions and results. This might create the opportunity for different pathways of innovation, more adapted to the capabilities and institutions of developing countries. Existing pathways are many time very difficult for new entrants from developing countries, since entry barriers are very high. Incumbent firms, block new entrants to these pathways in many ways. The possibility of alternatives is promising as discussed by some of the papers here.

A third important issue that emerges from the evidence in this special issue relates to the possibilities of *diversification related to NRBI* so necessary to reduce concentration and dependence on a few commodities. Two ways in which diversification can happen, as discussed here is through creating differentiated products within NRBI and/or the development of services, knowledge intensive or other kinds of services, in association with

NRBI. In both cases, knowledge creation activities and presence of a supporting innovation system are crucial to foster diversification. Also, the flexibility of firms and supporting innovation system to change over the time to adapt to changing challenges seems crucial.

A fourth significant issue linked to natural resource based development that emerges from the evidence of these papers is the *importance of buyers*, besides the acknowledged importance of suppliers for innovation in NRBI. Suppliers are important, because they are very often the place where technological innovations related to NRBI take place. Buyers are also crucial however, since they create the demands, and the incentives for innovations. They should commit financial resources, provide support to developers and create the spaces for experimentation. This is crucially important in the cases where demand is concentrated in a few large firms, like in mining, where given the nature of the business, these are typically MNCs. These companies might create little incentives to innovation, if they travel with their own global suppliers. Policies and incentives should be put in place to ensure a more balanced situation between users and producers of innovations so as to establish a fertile environment for interactive learning along the supply chain e.g. by encouraging MNCs to create incentives for local innovations (see e.g. Lundvall, 1985).

Lastly, understanding the role of NRBI in relation to climate change and the world's current violations of planetary boundaries is a key issue also addressed in the special issue. Given that NRBI are immersed in and feeds off the natural environment in mostly unsustainable ways, innovation and industry transformation in this set of industries seem crucial mechanisms for moving towards more *sustainable forms of natural resource production and use* (Lema, Johnson, Andersen, Lundvall, & Chaudhary, 2014). Indeed, separation between production and use of natural resources seems impossible when considering sustainability issues (Elzen, Geels, & Green, 2004). It is for instance difficult to imagine moving towards sustainable animal farming while maintaining current (and growing) consumption of meat (without strong population reductions). Although niches of alternative practices and technologies within agriculture and food consumption do exist, they still struggle to influence e.g. global value chains in food commodities. Changes in institutions such as consumer preferences and values are needed to create new markets. Regarding more sustainable production of natural resources, it seems that designing for example agricultural technology and practices primarily on the basis of the specificities of local ecological systems, is a fruitful direction for innovation to avoid breaching planetary boundaries (Andersen & Wicken, 2016; Maes & Jacobs, 2017; Tittone et al., 2016).

In the following paragraphs, we discuss in more detail the contribution of each one of the papers in this special issue.

The first paper by Marin and Petralia at a more general level provides evidence supporting the view put forward in this special issue that industries related to natural resources can provide significant opportunities for innovation. It uses evidence from Argentina and Brazil, and shows that in these countries, which a long tradition of exploitation and accumulation of capabilities around NRBI, manufacturing industries related to NRBI, traditionally classified as low tech have more technological opportunities than industries classified as high tech in the standard industry taxonomies, such as TV and communications and electrical machineries. In

this way the paper questions the relevance of existing taxonomies of industries that based on partial data from a few advanced countries typically classify traditional industries and industries linked to natural resources as having low technological opportunities or poor technological dynamism (Cimoli and Rovira, 2008; Hausmann and Rigobon, 2003, Hirschman, 1958; OECD, 2011; Lall, 2000; McMillan and Rodrik, 2011; Prebisch, 1950; Singer, 1975). This suggests that opportunities for innovation are not a fixed attribute of industries but depend instead on context-specific developments and are linked to the history of development of each country. Confirming existing ideas about the importance of linkages for innovation in these kind of industries the article shows that the role of clients is crucial, as an important source of technological opportunities. All the other sources, such as linkages to the knowledge base, feedbacks within the same industry and spillovers from suppliers do not show a significant impact.

The paper by Izuka and Gebreeyesus (2017) deals with the emergence of non-traditional NRBI with a focus on exports. It analyses the emergence and expansion of the export of flowers in Colombia and Ecuador and the same with blueberries in Chile and Argentina. This is an important phenomena for developing countries with export baskets very concentrated around a few commodities. The article emphasises the importance of building a system for the introduction and expansion of new exports in developing countries, it proposes thus to use the system of innovation framework to explore these activities. In the four cases a key role is played by pioneers, which take the lead and all the risks of starting a completely new activity. Interestingly, this role is played by different kind of actors in the four cases. In Colombia it is a foreign company, in Ecuador and Argentina, domestic business, and in Chile, two public institutions. Another very important factor in this case is the access to external markets. Here both actions taken by the individual entrepreneurs, governments and collective actions were very important. Public support appears very relevant also in all cases, so much that in the presence of almost no public support in Argentina, after a very good entry by a few domestic firms in the business of exporting blueberries the activity slow down. In Chile by contrast where the government play a crucial role in starting the business, and then handed it to private firms, the activity developed more than in Argentina expanding even towards more complex activities involved in the value chain, such as research and development in varieties.

The special issue contains three papers (Crespi, Katz, & Olivari, 2017; Joseph, Thapa, & Wicken, 2018; Nuur, Gustavsson, & Laestadius, 2017) that foreground the important role of domestic technology supplier industry in achieving natural resource based development. The papers describe different ways in which interactive learning and linkages between natural resource producers and suppliers, users, and knowledge organizations unfold. The findings cement the insight that nurturing an advanced supplier industry is a crucial part of innovation and development in NRBI.

The paper by Crespi, Katz and Olivari (2017) focuses on the emergence of knowledge intensive services (KIBs) associated to the production of natural resources in two Latin American countries. The emergence of KIBs has been emphasised as one of the main ways in which innovation can be fostered associated to NRBI because they both are a conduit for diversification and for intensifying innovation in the NRBI itself. Crespi et al analyse evidence from three key industries in Latin America, soybean seed developments in

Argentina and salmon and copper production in Chile and point to very important issues associated to the role of natural resources in fostering innovation and diversification. First of all, their paper provides important evidence confirming the idea that NRBI can be an important source for innovation and diversification into knowledge intensive activities in three very different industries. Developing countries trying to encourage and exploit these opportunities, however, they suggest, have to face important challenges. Five important issues that have to be considered are: local specificities; the growing importance of science for innovation in NRBI; the role of buyers, the accumulation of capabilities, and public policies. In the three cases it is clear that the emergence and expansion of successful KIBs is a process that requires advances in both private and public sector capabilities. Local specificities and advances in science were crucial in explaining the emergence of domestic KIBs for soybean seeds in Argentina. This case shows also that domestic firms entering the industry and take advantage of local specificities, can follow a different pathways to the one proposed and occupied by large MNCs engaged in these industries. However, the success of these firms depends on regulations and it is still not clear how they will progress with current regulations that respond to the demands and pressure of large MNCs. The case of salmon points clearly to the importance of the public sector and local regulations. The public sector was crucial in supporting the emergence of the sector, and then advancing regulations and institutions that support expansion, while looking after public interests. The importance of environmental regulations in this case not only serve public interests, but also private by looking after the resources and therefore the productivity in the longer term. Finally, the case of copper, which is less successful, points to the importance of buyers for innovation activities that are concentrated. Mining is an activity performed by a few very large firms, and therefore demand for knowledge and innovation are very concentrated. Large MNCs tend to use their traditional suppliers when they operate in a new location, particularly if this is in a developing country. A key challenge therefore for encouraging the development of KIBs is to introduce incentives for MNCs to use and nurture local suppliers.

The paper by Nuur, Gustavsson, and Laestadius (2017) explores processes of innovation and upgrading in NRBI via an in-depth study of the mining industry in Sweden. Challenging the view that mining is a low-tech industry applying “outdated” technology, they show that mining has experienced significant productivity growth in recent years via deployment of ICT and automation technologies. The mining processes from crushing to mineral powder are automated. This is made possible by the integration of several operations into one intelligent steering system. The authors suggest three key features of innovation in mining. First, that innovation is largely incremental due to high-capital intensity of the equipment. Second, innovation in mining is characterized by creative adaptation of general purpose technologies. Hence, at the level of process technologies, innovation can indeed be more disruptive. Third, these innovation processes unfold in linkages between mining firms and their suppliers and buyers. The study thus confirms the view that innovation in NRBI is often characterized by interactive learning relationships between users and producers. The authors further consider the implications of these innovation and industry dynamics for regional policy. Just as the mining industry is considered ‘backward’ by some, so are regions dominated by mining activities considered laggards in industrial development and as being without entrepreneurial

spirits, skills, and knowledge formation. However, documenting the high-tech nature of the mining industry changes the picture. The authors argue that key challenges for regional policy are to support continuous innovation in mining for example by helping to attract and train highly skilled workers that can work in these advanced mines.

Corresponding with the view that the success of NRBI in great part rests on the quality of the surrounding supplier industry and supporting innovation system, Joseph, Thapa, and Wicken (2018) argue for a "broad" innovation policy strategy as an essential element of natural resource based development. Inspired by the notions of "broad" and "narrow" understandings of national innovation systems (Lundvall, 2007; Lundvall, Johnson, Andersen, & Dalum, 2002), they describe a narrow innovation strategy as mainly focusing on science-based activities between natural resource producers and their interaction with knowledge producing organizations as research institutes and universities. Such a focus is typically on development and diffusion of high yielding varieties. A broad strategy, however, would incorporate a wider and more diverse set of actors and linkages between them including equipment suppliers and down-stream users. The authors argue that natural resource based development is only possible if coordinated innovation and upgrading take place across producers, suppliers, and buyers in a natural resource based network. Such networks further require the support of a dedicated innovation system to grow. Against this background, the authors present a case study of the natural rubber industry in Kerala, India, which has recently gone through a prolonged period of crisis. In a counterfactual way, the authors suggest that the downfall of natural rubber production in Kerala in part can be explained by the absence of a "broad" innovation policy strategy. They identify a lack of interactive learning and interaction between rubber producers and users of rubber (manufacturers), and a lack of interactive learning between rubber producers and equipment suppliers. They propose that such a strategy leaves the NRBI rigid and vulnerable to changes in the market. It also inhibits the innovation and industry dynamics that underpin natural resource based development. In conclusion, the authors suggest that policymakers in the region should broaden their perspective on innovation policy for NRBI by involving a wider and more diverse set of actors to develop more inclusive innovation systems.

The paper by Ranestad (2017) explores the determinants of natural resource based development by asking: what can explain the divergent experiences of the mining industry in Chile and Norway? Despite rather similar starting points, the Norwegian industry achieved continuous innovation and upgrading to stay globally competitive while the Chilean industry struggled. Ranestad focuses on organizations that contribute to generating, diffusing, and using knowledge in the areas of education and training of technicians and specialized engineers, technical mining manuals instructing the work, international knowledge transfers, and geological surveys in the period 1870s to 1940s. Ranestad finds that the knowledge organizations serving the NRBI in the two countries appeared identical but that the functions they played in the respective industries differed significantly. In Chile, the organizations had very limited resources available and their inactivity ended up blocking development, diffusion, and use of knowledge. In Norway, rather similar organizations had significant resources and contributed to maintaining an innovative industry, which could adapt to new trends. Ranestad highlights the role public policy in explaining these differences. In Chile, the



industry called for more resources to geological mapping, knowledge transfers, and education of engineers but these calls were largely ignored. On the other hand, the Norwegian government was very active in supporting knowledge development in mining but also more generally in society (basic schooling). Hence, some underlying institutions concerning values and preferences of elites and the broader society may be fundamental for understanding natural resource based development. Regarding the role of the supplier industry, Ranestad notes that MNCs dominated the industry in both countries. However, while in Chile MNCs had an 'enclave nature' with few and shallow linkages to local economy, in Norway they were more effectively integrated with more and stronger linkages to the local economy. One reason for this is that in Chile there was a large technology gap between local supplier firms (relying on rudimentary / primitive methods) and MNCs that applied state-of-the-art. In Norway, local supplier firms were often more technologically advanced than MNCs in mining. Again, this points to the importance of high-quality supply industry to succeed with natural resource based development.

The paper by Johnson and Villumsen (2017) considers sustainability aspects of NRBI. Here the authors confront the broader question of whether sustainable development and natural resource based development are compatible. In terms of environmental impact, the authors distinguish between source (e.g. resource depletion) and sink problems (e.g. pollution). An interesting difference between manufacturing industries and NRBI is that the former mainly influence nature via sink issues. NRBI are more directly embedded in the local natural environment and thus unsustainable use of nature can directly undermine the production of natural resources. That link is only indirect and very long-term for manufacturing industries. Some NRBI, especially biotic ones, face an imperative to respect and understand the natural environment to greater extent than manufacturing industries (Iizuka & Katz, 2010). In this context, the authors analyse the state of the world agricultural industry. By reviewing a range of existing studies, they conclude that agriculture currently contributes heavily to moving global ecosystems beyond the threshold of safe operating space. Different possible pathways towards sustainable development in agriculture do exist. Any such path must however consider population growth, the amount, content and distribution of consumption, and technical development. The authors emphasize that changes in these factors presupposes pervasive institutional change such as changing consumer routines, new land rights to avoid deforestation, and the need for a new ethics. Such new ethics include new ways of valuing nature that can take us beyond short-term price competition and global commodity markets, and ultimately make world agriculture capable of operating within the given planetary boundaries. The authors see the emergence of a new ethics as the catalyst for other institutional changes that, in turn, support technological and structural change enabling sustainable agriculture within planetary boundaries. The authors further argue that despite having sufficient information about unsustainable forms of agriculture as well as the possible solutions for them, there has still been very little progress. This is seen as a symptom of the power wielded by incumbent actors to avoid 'creative destruction' in agriculture. In conclusion, the authors conclude that there is a need for 'inclusive institutions' (Acemoglu & Robinson, 2012; Andersen & Johnson, 2015) to undo the systemic and structural lock-in described in the paper.

## 5 Further research

In this last section, we highlight four issues we consider particularly promising for further research although we acknowledge that the features of innovation in NRBI discussed above all require further scrutiny and research. First, a key theme in this special issue that merits more attention is how the interplay between natural resource knowledge idiosyncrasy and innovation can give rise to new path creation in natural resources. From some of the case evidence it was suggested that due to local specificities new directions of innovation can emerge associated to natural resources. This can create important opportunities for innovation in firms; particularly in developing countries, which face huge barriers to entry into existing industries, dominated by large international players that control not only technology but also institutions (e.g. IPR, biosafety). The evidence presented here however is partial, emergent, and scarce. More research needs to be pursued to understand better whether this opportunity exist in different contexts, what needs to be done to expand it, and the challenges to expand. Recent reflections on innovation systems research acknowledge that there is only limited understanding of how different properties of the natural environment influence emergence of new technologies (Bergek et al., 2015).

Second, the management of natural resources is of great importance to the world's endeavour to move towards more sustainable forms of production and consumption. In our view, much of the Innovation Studies research on sustainability focus on transformations and innovations in the end-use industries such as electricity, transport, water, and heating without much consideration for the, often global, supply chain feeding these changes with iron, steel, lumber, and rare earth metals. Hence, there is a need for connecting the sustainability transition in the technology-using sectors in the Global North with the production of natural resources in the Global South partly because the latter could seriously impede the former (see e.g. Jacobson & Delucchi, 2009; Kleijn, van der Voet, Kramer, van Oers, & van der Giesen, 2011; Kramer & Haigh, 2009). This would be in line with recent advances in innovation system studies that call for more detailed analysis of the types and extent of innovation in different technology supply chain segments as well as how they are configured and interact across place (e.g. electrical vehicles in Denmark and lithium mining in Bolivia) (Stephan, Schmidt, Bening, & Hoffmann, 2017). Such studies could however also explore whether and how global sustainability transitions are affected by the particularities of innovation in NRBI that we have identified above. Innovation in NRBI is also crucial for climate change adaptation. As ecological systems themselves are starting change in reaction to climate change, NRBI will be particularly vulnerable which suggests that current knowledge of local specificities could become obsolete; both in the North and in the South. The latter suggests that new and significant investments in knowledge about local specificities will become increasingly important in the future if production of e.g. food, wood, and fish is to be maintained at current levels. However, to our knowledge there is little or no work this type of challenge.

Third, we know that NRBI—although some more than others—are exposed to market volatility through boom and bust cycles. We know rather little however about how such swings influence innovation. Crespi et al. (2017) shows that the demand of natural resource

producers for services and products from the supplier industry is procyclical. Corresponding to the latter, recent research suggests that in downturns firms in the supplier industry attempt both market and technology diversification to stabilize their income stream (Andersen & Gulbrandsen, 2018; Mäkitie, Normann, Gonzalez, & Thune, 2017). A related study further shows that some supply firms incorporate the market volatility into their business models and innovation strategy i.e. in the terminology of March (1991), in booms they ‘exploit’ and in busts they ‘explore’ while they wait for the market to boom again (Gonzalez, 2018). This particular feature of innovation management in NRBI has, to our knowledge, however not been sufficiently explored. How can competence destruction and soaring unemployment in periods of downturn, be understood and explained in a way that can inform future public policy?

Lastly, most studies reviewed in this introduction focus on innovation in natural resource production via different types of interactive learning. There are less studies considering industrial and technological diversification on the basis of natural resource production. The distributed knowledge bases underpinning the supplier industry and its innovation activities are key to achieving long-term natural resource based development. A central question is to what extent and how these knowledge bases can “spillover” and be redeployed in other industries to strengthen innovation activities and benefit the wider economy. Besides the anecdotal evidence presented above, we know of little research that pursues such questions in relation to natural resources.

## **Acknowledgements**

This Special Issue has its origins in the Globelics community of global innovation researchers, which has identified natural resources as an important area in need of further research and an area where better-informed strategy and policy can make an important difference. The theme of this special issue has been discussed firstly at a 2-day Globelics seminar entitled “Natural Resources, Innovation and Development” in Copenhagen, March 2014, and subsequently at a special session of the Globelics Annual Conference in Addis Ababa in October 2014. The community afterwards produced a Globelics Thematic Review on the topic “natural resources, innovation and development”. The special issue editors are thankful for comments and support from Tim Turpin and Christina Chaminade as well as Journal Editor KJ Joseph. The early phase of this special issue was enabled by funding from the Swedish International Development Agency. Allan Dahl Andersen also acknowledge support from the Norwegian Research Council project number 237677.

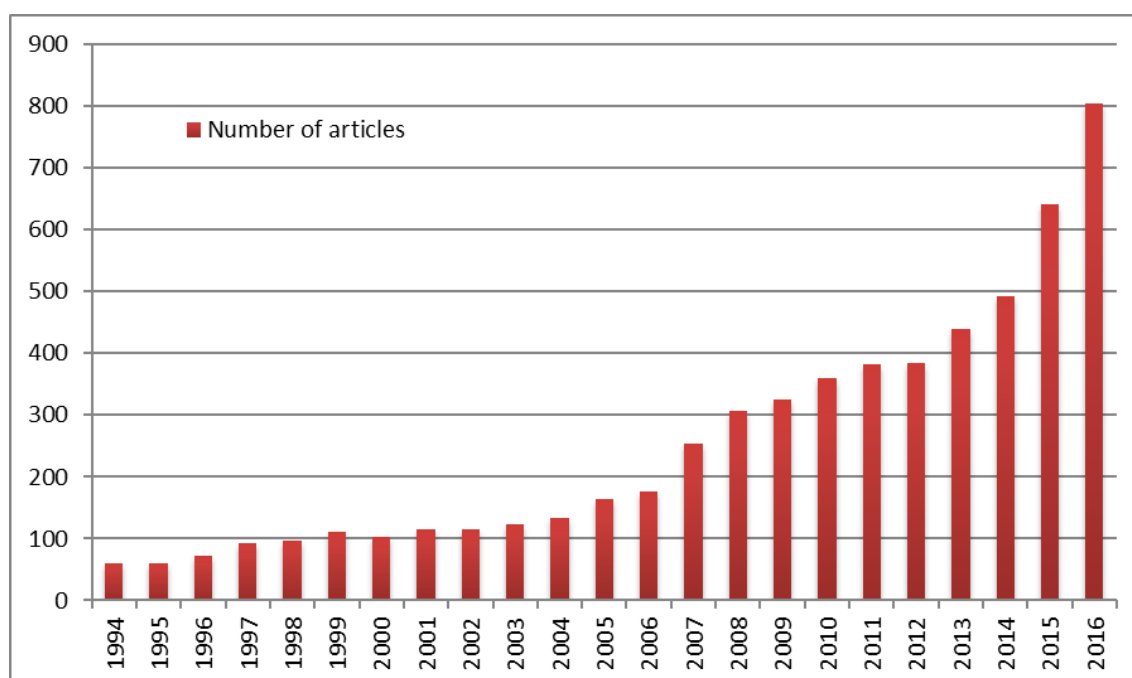
## Appendix: methods

### *Social science research on natural resources and development*

Using ISI Web of Knowledge we applied search queries that combined typical indicators for, on the one hand, research on natural resources, and, on the other hand, research on development, see table A1. This resulted in 6405 articles and with a substantial increase in recent years, see figure A1.

**Table A1: key terms in NRBI and development.**

Natural resources	Development
Natural resource(s)	Economic growth
Resource-intensive	Economic development
Commodity	Development
Primary sector	
Extractive industry(ies)	



**Figure A1: Number of articles about natural resources and development in social sciences 1994-2016.**

This growing body of research is in terms of scientific disciplines (as defined by ISI) dominated by Economics, and by Management and Business studies, see Table A2.

Also, we used the bibliometric software visualizer programme VOSviewer (Van Eck & Waltman, 2010) to further analyse the abstracts of the 6405 articles. We generated a “relevance score” for key terms in the paper abstracts. The measure reflects how central or important a term is based on how it occurs in relation to other words. It is a measure of how general the term is. For example, a term such as “method” could occur in many different types of articles, without saying much about the content. If a term occurs randomly across the text, it receives a low relevance score. If the term is clustered in specific contexts and specific constellations of words, it receives a high relevance score. We include here the twelve terms

with highest relevance score (we removed terms that did not immediately have any research-relevant meaning such as “student” or “share”), see results in Table A3

**Table A2: Dominant disciplines**

<b>Social Science Discipline</b>	<b>%</b>
Economics	32
Management & Business	19
Environmental Studies	16
Planning Development	15
Geography	13
International Relations and Political Science	8

**Table A3. Occurrences and relevance score for key terms**

<b>Term</b>	<b>Occurrences</b>	<b>Relevance</b>
<i>Resource curse</i>	159	5,97
<i>GDP</i>	161	5,74
<i>Foreign direct investment</i>	109	5,52
<i>Commodity price</i>	173	5,03
<i>Export</i>	350	4,87
<i>Natural resource management</i>	257	4,03
<i>Price</i>	462	3,79
<i>Biodiversity</i>	116	3,59
<i>Conservation</i>	409	3,29
<i>Local community</i>	157	3,28
<i>Trade</i>	521	2,94
<i>Economic growth</i>	721	2,87

The relevance scores of key terms confirm the dominance of Economics with a focus on growth and trade and above all the resource curse. Biodiversity, conservation, and local community could be linked to the activities in Environmental Studies and Planning Development, cf. Table A2.

### ***Innovation Studies and natural resources***

It is not possible to identify Innovation Studies by use of the science categories classified by ISI Web of Knowledge. Among the 6405 articles identified above, cf. figure A1, the term “innovation” appears in 475 articles (title, keyword, abstract) accounting for around 7 per cent

of the population. However, use of the term innovation is not the sole right of innovation scholars. Therefore it would be misleading to take that selection as representative of Innovation Studies work on natural resources. Therefore, we chose to delimit our search space via key journals for innovation research.

Our definition of Innovation Studies follows Martin (2012) in using Research Policy's definition of "Innovation Studies". Hence, we seek to delimit the field to include studies analysing, understanding and effectively responding to economic, policy, management, organizational, environmental and other challenges posed by innovation, technology, R&D and science. This includes a number of related activities concerned with the creation of knowledge (through research), the diffusion and acquisition of knowledge (e.g. through organizational learning), and its exploitation in the form of new or improved products, processes or services." Two previous articles (Fagerberg, Landström, & Martin, 2012; Fagerberg & Verspagen, 2009) have combined identified 27 journals where Innovation Studies research is mostly published (although the journals are outlets for other, related, disciplines as well), see table A4. These journals constitute the first delimitation of the field of Innovation Studies in this literature review.

**Table A4: selected key journals**

"American Economic Review"	"Journal of Industrial Economics"	"Research Policy"
"Academy of Management Journal"	"Journal of International Business Studies"	"Small Business Economics"
"Administrative Science Quarterly"	"Journal of Management Studies"	"Strategic Management Journal"
"Cambridge Journal of Economics"	"Journal of Product Innovation Management"	"Structural Change and Economic Dynamics"
"Economics of Innovation and New Technology"	"Management Science"	"Technological Forecasting and Social Change"
"Human Relations"	"Organization Science"	"Technology Analysis & Strategic Management"
"Industrial Change and Corporate Dynamics"	"R & D Management"	"Technovation"
"International Journal of Technology Management"	"Rand Journal of Economics"	"Academy of Management Review"
"Journal of Evolutionary Economics"	"Regional Studies"	"Management Science"

Using the web of science database including the full range of data (period 01.01.1994-25.01.2018) we found 41,711 published papers in these journals. These, however, still constitute a rather diverse set of social science disciplines. As a second delimitation of the field of Innovation Studies, we therefore reduce our search space within these journals to only

contain papers that have “innovation”, “learning” or “technology” in keywords, abstract, or title. This gives us a population of 16,085 articles.

In order to compare the occurrence of innovation research on NRBI with other topics, we distinguish between the primary sector (NRBIs), the secondary sector (manufacturing industries) and the tertiary sector (services and high-tech areas). We selected five thematic and 10 empirical keywords for each category to use as search string, see table A5. This will give us both information about the extent of innovation research on NRBI as well as an idea of the relative attention paid to NRBI compared to other sectors in the economy.

**Table A5: keywords for topic search.**

NRBI		Manufacturing		Service	
Thematic	Empirical	Thematic	Empirical	Thematic	Empirical
natural resources	agriculture	high-tech	furniture	service	creative industry
low-tech	mining	manufacturing	car / automotive	health	media
resource curse	oil	industrialized	aviation	education	tourism
primary sector	petroleum	fabrication	medical / scientific instruments	transportation	research
commodity	coal	secondary sector	television	energy distribution	design
	fishing		ICT		engineering
	pulp and paper		machinery		retail
	food		chemical industry		finance
	forestry		pharmaceutical		insurance
	animal husbandry		textile		consultancy
	raw materials		robotics		

As illustrated by Figure 1 (only shows until 2017), manufacturing accounted for 3289 of the 16,085 articles (about 20%), and the service sector has been studied in 832 articles (around 5%). The primary sector has been analysed in 137 studies and with no significant increase in the latter years. This is as little as 0.85% of all innovation-related articles in the period. Our first round search resulted in 211 articles on NRBI but by manually reading the 211 abstracts to check for false positives, we excluded 74 articles that were unrelated to innovation in NRBI. Two of the authors did the latter assessment in collaboration. One author led the coding and another author coded about 50% of the papers to validate and check the first

coding supplemented by frequent calibrating discussions to ensure consistency. The subsequent coding followed the same procedure.

Inspired by our reading of the abstracts, we further categorised the 137 papers into three main groups according to their content. A first group of 47 papers are empirically motivated, they analyse change or innovation in a NRBI setting by use of Innovation Studies vocabulary, and they keep conclusions and insights empirical. A second and largest group of 78 papers are theoretically motivated and seek answers by analysing NRBI. These papers typically don't mention the natural resource aspects of the empirical material. Instead, the NRBI becomes an incidental context for generic theoretical questions (e.g. what is the effect of management team educational background on innovation?). A third and smallest group counting 12 papers are either theoretically or empirically motivated with a focus on conceptually understanding innovation in NRBI and their conclusions typically try to depict particular features of innovation in NRBI, see Table A6. The small size of the last group provides a further indication of the little attention NRBI have received in Innovation Studies.

**Table A6: Content of NRBI papers**

<i>Paper's connection to NRBI</i>	No.
1: Interest in NRBI is empirically motivated or it is an empirical paper including NRBI	47
2: Theoretical part not about NRBI, but paper includes NRBI as a case	78
3: Paper is conceptually interested in NRBI	12

We also computed a relevance score for key terms using the abstracts of the 137 articles, see Table A7. These scores suggest that the research concentrate attention around food and biotech industries, and often apply a company and R&D perspective. However, the relevance scores are quite low which suggests a significant heterogeneity among the papers as also indicated by results in Table A6. The 137 papers are concentrated in the following journals: Technological Forecasting and Social Change (30%), Research Policy (29%), Technology Analysis and Strategic Management (13%), Technovation (8%), and R&D Management (7%). Lastly, among the 137 articles, only 9 explicitly address a developing country context.<sup>3</sup>

**Table A7: Relevance score for NRBI articles (see Table A3 for calculation)**

<b>Term</b>	<b>Occurences</b>	<b>Relevance score</b>
<i>Food industry</i>	18	1,77
<i>Natural resource</i>	11	1,62
<i>Biotechnology</i>	12	1,36
<i>Company</i>	18	1,3
<i>India</i>	12	1,2
<i>R&amp;D</i>	14	1,08

<sup>3</sup> Search string in title, abstract, and keyword: "Developing countries" or "Developing country" or "low-income" or "underdeveloped country" or "poor country".



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