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Scarcity in the twenty-first century: How the resource nexus affects management

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SCARCITY IN THE 21ST CENTURY: HOW THE RESOURCE NEXUS AFFECTS MANAGEMENT

Since the advent of the 21st century and especially since the food and financial crisis in 2008, concerns about natural resource availability have resurfaced. While scarcity concerns date back hundreds of years and are foundational to economics, how scarcity is interpreted or framed has evolved significantly in the last two centuries. In this chapter, we recount the evolving scarcity discourse and specifically address the most recent iteration that centres on the idea of a resource nexus. While significant attention to the nexus has been paid by policy-makers and scholars interested in especially water, management scholars have so far remained absent from these debates.

Given recent calls to address grand challenges in management and more specific calls for work on scarce natural resources, both this book and this chapter are timely endeavors (George et al., 2015). The munificence of the natural environment is an important issue for the well-being of mankind in general which affects the organization of the (post-) industrial economy. Various trends are suggestive of mounting resource needs that somehow need be met.

Global population growth in combination with millions of people being lifted out of poverty following industrialization has increased pressure on natural ecosystems as demand for energy and water-intense food crops climbs. In conjunction with this trend, urbanization and violent conflict are driving mass migrations that challenge both natural systems and political institutions. While the human and social toll of violent conflict is evident, it is nonetheless important to recognize that for every person dying in armed conflict, about a 1,000 people die due to lack of access to clean water or as a consequence of household air pollution[1]. The decreasing ability of natural environments to function amidst on-going, unabated human interference is a contemporary, urgent problem. This reduced absorption capacity is a form of resource scarcity where we still lack important scientific understanding. As a consequence, governments have invested in security measures

[1] IEA (2016) numbers put the total number of deaths due to air pollution alone at 6.5 million while the WHO estimated that almost 25% of deaths in 2012 (12.6 million) were due to unhealthy living environments (Lindmeier et al., 2016).

and hedges to scarcity, especially when it comes to food and energy independence, resulting in the phenomenon of land grabs as a form of foreign direct investments made by governments and sovereign wealth funds (ADB, 2013; Andrews-Speed et al., 2012; Lee et al., 2012; Xynteo, 2012).

The combination of these and other trends poses serious challenges for organizations that are directly or indirectly dependent on natural environments' functioning. While challenges might be more pronounced for those organizations in the extractive industries, all organizations ought to ensure that their employees and community stakeholders can sustain themselves without experiencing undue harm caused by the organization's operations. In what follows, we first provide a short overview of the evolving scarcity framings culminating in the current nexus approach (Allouche et al., 2015; Andrews-Speed et al., 2012; Foran, 2015; Hoff, 2011). Our review of the literature allows us to present a framework of a multi-dimensional nexus in which source and sink resources and the natural dynamics underlying them interact with techno-economical, socio-political, and market processes. We then propound a managerial approach that revolves around dynamism, munificence, and complexity which are central constructs in organizational theory (Anderson and Tushman, 2001). Building on theoretical insights gathered from prior research on organizational ecology and resource dependence theory (Hannan and Freeman, 1977; Pfeffer and Salancik, 1978) as well as on current actions of companies to deal with nexus problems, we propose complementary strategies that can be used as nexus management strategies in a hyper-connected world.

Framing Scarcity in Time

Frames are cultural structures that are "produced and shaped by the political economy of the society" or through "the deliberate attempt of individuals or groups to structure public discourse in a way that privileges their goals and means" (Reese et al., 2001, pp., p. 147). As a consequence, frames tend to be in a permanent state of emergence or decline while contradicting frames can co-exist peacefully or can be involved in an epistemic battle for primacy. The importance of how scarcity is and has been framed over the last two centuries can hardly be overestimated. If one were to frame global hunger as the inability of the available land to produce enough food for a growing population one has to have a radically different conversation than when we acknowledge that "per capita calorie production has increased from 2,280 to 2,800 kcal per day" (Hoff, 2011, p. 7). Knowing that a healthy diet requires on average

2,000 kcal per day per person the hunger problem shifts from a productive capacity issue (frame 1) to a distribution and justice issue (frame 2).

Of the three stages involved in addressing any issue (selection, framing, and resolution), issue framing has the most profound effect on the final result (Bardwell, 1991). This is especially so when an issue's framing affects an open community of people who use that framing as a basis for problem solving trajectories. In this context, framing can be understood as "a process that can help members of a community to evaluate the benefits ("wins") and drawbacks ("trade-offs") of a potential course of action" (Rice, 2012). The epistemology of framing requires a recognition that "any system is subject to multiple forms of interpretation by a range of actors dependent upon how scale, boundaries, key elements, dynamics, and outcomes are labelled and categorised, and how assumptions are made based on varying degrees of subjective/value judgements" (Middleton et al., 2015).

Failure to ensure effective problem framing and subsequent actions can lead to (1) defining a problem such that it cannot be understood by diverse interests, (2) defining the problem such that it cannot be solved, (3) solving the wrong problem, and (4) a mismatch between problem and solution, e.g. working on a technical solution for a problem that, at its core, requires a social or political solution (Clark and Stankey, 2006). These points are relevant to the framing of scarcity as they crucially affect how management ought to think about coping with scarcity now and in the future.

Scarcity

Concerns over the availability of natural resources are recorded as far back as the biblical Old Testament (Gleick, 2014) and resource scarcity has been on the agenda of economists, politicians, and environmentalists for more than a century. However, while the word "scarcity" has remained in fashion over time, what it exactly refers to has been subject to considerable variation. Malthus (1798) feared agricultural land would be incapable of providing enough food for an ever-growing population, while Ricardo (1817) stated that scarcity was a function of different grades of ore quality that could be extracted at a reasonable cost. This implied a transition from *the biophysical* to the *techno-economic* as the focal constraint on availability. The conservation movement in the early 20th century favoured restraint from resource use, calling on our (intertemporal) morality and providing a more *social* mechanism that determines availability. Hotelling (1931) later conceived of an "economics of exhaustible resources" and concluded that scarcity is transparent in resource prices hence providing a *market rationale* for scarcity.

The rapid growth of the post-war economy sparked doubts as to whether market prices were suitable mechanisms to avoid resource exhaustion. Tober (1974, in Brown and Field, 1978) for instance submitted that prices of wild pigeons remained very stable until their complete extinction in 1890 and social psychologists have come to find that people have a strong tendency to overconsume physical, spatial, and temporal resources (Herlocker et al., 1997), with the Easter Island as the prototypical example. Such notions were exacerbated by the rise of the environmental movement which exposed the links between environmental damage and industrial or agricultural processes which lead to the realization that *ecosystem constraints* could limit the productive capacity of the land (Carson, 2002), which in turn provided the feeding ground for the environmental movement (Grisworld, 2012).

Later, the seminal "Limits to Growth" foresaw economic collapse due to food and mineral shortages (Brundtland and WCED, 1987), thus echoing Malthus, while the follow-up in 1992 emphasised the impact of resource exploitation on *ecosystems* again. The last two decades have chiefly focused on these ecosystem implications with climate change and global warming becoming an integral part of the resource constraints agenda. Specifically, the Carbon Tracker has argued that many fossil fuel assets will never be allowed to be mined if governments indeed are willing to enforce the 2 degrees centigrade target that has been agreed in the UNFCCC COP process which in turn has been stretched to 1.5 in Paris in 2015 (Leaton et al., 2013; UNFCCC, 2015), hence providing a *political constraint* on resource availability. Similarly, the modern discourse on resource security is also related to both social and political constraints imposed on natural resources through quota and strategic state interventions (Buijs and Sievers, 2012; Defra, 2011). Finally, the discourse on planetary boundaries has promoted the idea of nine essential ecosystems that each are sensitive to transgression of their capacity to absorb negative externalities (Rockström et al., 2009). While the planetary boundaries hypothesis has been built on the narrative of "how many planets do we need to sustain our current consumption", it has failed to answer how the interconnections between the affected ecosystems could create irreversible thresholds. Specifically this omission is being addressed by the resource nexus concept, the latest discursive step in our understanding of scarcity which incorporates system emergent properties between resource systems and therefore uncertainty in system behaviour. This discursive evolution shows that scarcity has been iteratively framed as being chiefly driven by biophysical, techno-economic, market, socio-political, and eco-system constraints.

Nexus Thinking

Nexus has been described as “the new kid on the block” in recent resource debates. However, the first real mention of the food-energy nexus dates back to a 1983 program of the United Nations University (Scott et al., 2015) and nexus thinking itself is rooted in both input-output analysis and the systems thinking behind the foundational “Limits to Growth” (Meadows et al., 1972). Yet the modern nexus discourse really only dates back to the beginning of the 21st century with early studies mainly focusing on the link between water and energy generation. Chiefly since the global food crisis in 2008, the nexus debate has started to broaden its horizons by considering more than two natural resource systems concurrently. Now, the nexus commonly refers to the explicit interlinkages between water, energy, food (the so-called WEF agenda), and to a lesser extent climate change and land (Allouche et al., 2015; Foran, 2015). The key characteristic of the water-energy-food nexus is that each of these three elements require the other two as inputs. Since 2010, nexus issues have been raised by governmental organizations such as the UN General Assembly, the European Commission on Development, World Bank, the Global Water Partnership, and the US National Intelligence Council.

While the nexus frame can be understood as a rebranding of much thinking about sustainable development, the green economy, resource scarcity and environmental justice, in its simplest form it refers to “an approach that integrates management and governance across sectors and scales” (Hoff, 2011, p. 7). As much of the nexus work has been conducted with a background in water research, some others have voiced concerns, stating that the nexus approach “leads to demand-led technological and market solutions that ignore the supply-side limits and political dimensions in terms of control over and access to resources” (Allouche et al., 2015, p. 611). These authors argue that nexus research has focused primarily on establishing the biophysical interdependence between water, energy, and food (and land) while ignoring that the production and use of these resources are very often political actions and thus constrained in terms of who can obtain resources and at what price. In a similar vein, Middleton et al. (2015, p. 630) have sought to establish that “the nexus is a political process, not just a technical one”.

Beyond the natural and political frames, Andrews-Speed et al. (2012, p.5) argue the resource nexus "comprises the numerous linkages between different natural resources and raw materials that arise from economic, political, social, and natural processes". Others attempt to further broaden the boundaries and usefulness of the nexus by infusing it with concepts such as environmental justice (Middleton et al., 2015), resource inequality and social instability (Allouche et al., 2015), regimes of provisioning (Foran, 2015), and networks of action (Villamayor-Tomas et al., 2015). At the opposite end of the spectrum, Scott et al. (2015, p. 20) seek to narrow down the application of the nexus approach by zooming in on how it forces us to think about resource recovery in a more systemic way. Hoff (2011, p. 7) described the objective of nexus thinking as "a reduction of negative economic, social and environmental externalities [that] can increase overall resource use efficiency, provide additional benefits and secure the human rights to water and food". Perhaps because the nexus framing is still in flux, Middleton et al (2015) have proposed that the nexus has taken on the characteristics of a nirvana concept as it embodies an ideal image of a normative world view to which society should aspire.

Scarcity in the Resource Nexus

When it comes to framing scarcity in the resource nexus, there is broad agreement about the causal attributions that make the present frame distinct from past frames. First, the doubling of the world economy between 1998 and 2008 in PPP, population and middle class growth with changing energy and food preferences, and increasing urbanization are vital demographic and economic factors that strain natural resource systems. Second, global trade rose from $5.5 trillion to $16 trillion in the same 10 year period increasing the interconnectedness of the economy and the increasing adoption of Western lifestyles. The traded percentage of food produced has increased from 10 to 15% between 1970 and 2000. Although the financial and food crises of 2008 have pushed down the growth of global trade from about 7% per annum between 1960 and 2008 to below 3.5% since, globalization might be slowing down, but is not retracting (Wolf, 2016). Thus, disturbances and shocks in markets are now globally contagious. But, limiting global trade and promoting protectionist isolationism will worsen local shortages, especially in import-dependent, underdeveloped nations.

Global drivers can become more important than local drivers while, at the same time, increasing connectivity enables local turbulence to spread further and faster than ever before (Andrews-Speed et al., 2012). This lead Sir Martin Sorrell, CEO of WPP, to say that in this era of hyper-connectivity, companies must treat even small problems as company-wide reputational threats and "prepare global responses to local crises" (Xynteo, 2012, p. 12). This business need is only exacerbated by new technologies and social networks allow proliferation of un-validated information while also enabling better monitoring and stronger social movements. On top of that, at the political level, there has been an increase in terra-complexity, characterized by a reduction of US power, the emergence of the G20 from the G7, the rise of populism and nationalism, and the rapid ascent of public, private and state-owned firms as key actors in solving social issues.

Against this background, Andrews-Speed et al. (2012, p. 3) postulated that the focal challenge is "to govern resources across countries and companies within the absorptive capacity of the planet", hence focusing on natural ecosystem limitations. Others have suggested that "while water, energy and food security have so far been mainly constrained by unequal access, humanity is now also approaching limits in global resource availability and sink strength" (Hoff, 2011, p. 11). Although others have suggested that actual constraints on biophysical availability are much less restrictive than once imagined, there is nonetheless broad agreement that "whether or not resources are actually running out, the outlook is one of supply disruptions, volatile prices, accelerated environmental degradation and rising political tensions over resource access" (Lee et al., 2012, p. xi)

Towards a New Framing

Foran (2015) suggested that the nexus is still an immature concept that is in need of more critical conceptualization. In this light, Villamayor-Tomas et al. (2015) point out that most nexus approaches are rooted in systems thinking which focuses on the natural interactions while downplaying the vital role of private supply chains, human agency, and political institutions. Foran (2015) suggests that a combination of systems complexity thinking that asks how do efforts for domain A affect other variables of interest in domains A, B, C, D with a more critical social science approach that investigates historical power relations and their relationship to poverty, is required to bolster understanding. Relatedly, Andrews-Speed et al. (2012) suggest scarcity is a multi-dimensional concept and that the nexus approach "stems from the geo-chemical-ecologic conditions as well as from their socio-technological-economic-political contexts" (p. 6).

Extending this line of reasoning we propose a nexus frame to natural resource scarcity that departs from the interplay between *source and sink resources*. Source resources capture the biophysical availability of known and unknown reserves of natural resources on which human production and consumption activities depend. Sink resources are the different natural and social ecosystems and biomes upon which the planet relies to store, assimilate, and/or transform waste pollutants and contaminants originating from human production and consumption activities. Sink resources thus determine the earth's capacity to deal with the negative externalities caused by exploitation of source resources and potentially (if negative feedback loops come into play) also by the further deterioration of other sinks. In conjunction with this framing of resource scarcity around sources and sinks, we propose three dimensions that are essential constraints to resource availability in the Anthropocene.

The *techno-economic dimension* determines which forms of resource extraction are technologically feasible, economically efficient, and which externalities are associated with the required industrial processes to turn a resource into a useful input. Breakthrough technologies can enable cheaper extraction or bring previously inaccessible source resources within the economic fold and can hence increase the known and accessible stock of resources, though often at a price: Energy return on investment has been falling in most places in recent decades as the low hanging fruits are increasingly behind us (Hall et al., 2014). Digging in more challenging natural environments such as the Arctic and in deep waters poses grave environmental risks as the Deepwater Horizon disaster made clear. The development of new natural energy resources like oil and tar sands and shale oil and shale gas is associated with lower energy return on investment as well as significant damage to sinks (Hughes, 2013; Yaritani and Matsushima, 2014). The same goes for deep exploration projects such as the copper mining project Resolution in the USA which cost billions before any return is expected (Phillips (Phillips, 2016), while other mining projects' failures such as the Samarco Tailings Dam breach could top the Deepwater disaster as the most expensive environmental catastrophe ever (Frik, 2016).

The *market dimension* captures the allocation of capital and skills to specific ends, distribution processes, and an incentive system that values natural resources in monetary terms, thereby enabling trade. Most sink resources are not valued in the market as no clear property rights are assigned to them or fail to be enforced. Opaque markets - in which transparency is low - heighten scarcity while leakage in distribution systems adds a layer of waste as well. Despite decades of economic research, there is still no agreement as to whether scarcity is transparent in market prices (Hotelling, 1931; McMahon and Mrozek, 1997; Norgaard, 1990). Moreover, natural resource economists have argued that those firms that base strategic decisions based on actual price movements will inevitably be too late to implement meaningful change (Alonso et al., 2007). Schillebeeckx and George (2016) summarize that four reasons coexist to explain why temporary imbalances in these natural resource markets are likely: (1) the capital intensive nature of most commodity value chains; (2) poor price signal generation due to corporate reserve commercial sensitivity and limited time horizon of exploration; (3) up-, mid-, or down- stream concentration in the value chain creating power differentials which also reduces transparency; and (4) the geological co-dependencies between different resources

The *socio-political dimension* ought to provide a counterweight to the market while at the same time steering the direction of technological progress. This dimension crucially is responsible for exerting care for those resources that escape market valuation but are nonetheless of high value to human and planetary survival. Social issues such as human health, poverty, and migration influence this dimension and further affect the actual availability of resources as governments or civil society itself can constrain mining efforts for idiosyncratic reasons. The same goes for the rules imposed by government to ensure the industrial system does not excessively stress the sinks' resilience, as they successfully did when enforcing greater fuel efficiency in cars after 1978 and as was done with the ban on CFCs to protect the Ozone layer, formalized in the Montreal Protocol. In addition, we have to ask under which social regimes the nexus elements are produced and how that relates to profit, power, and social change (Foran, 2015). The figure below summarizes the framing of scarcity in the resource nexus. The plus or minus symbol at the sink level indicates whether a sink is made more resilient (+) or less so (-).

Table 1: A Nexus Frame for Resource Scarcity

	Constraints on Resource Availability		
	Techno-economic	**Market**	**Socio-Political**

Source	EROI, extraction technology, cost, exploration	Price, supply elasticity, concentration, interdependence, imbalances	Global trade, resource nationalism, social equity, indigenous rights, regulation
Sink	Externalities (-) Geo-engineering (+), planetary thresholds (-)	Tragedy of the commons (-), internalization (+), property rights (+)	Health (-), poverty (-/+), conflict (-), social action (+), migration, carbon tax (+)

It is important to note that this frame presumes a holistic perspective. It does not explicitly account for interests and strategic or political choices taken by the focal actors who can choose to ignore certain aspects of the frame or color them in differently based on their idiosyncratic position that drives them to ignore and reshape certain aspects. As such, this frame interacts with scale perspectives (global, national, regional, local), and with role perspectives (government v corporation v NGO v individual). National governments e.g. will focus on endowments or lack thereof and policy will be determined by the relative ease by which critical resources can be acquired. Land acquisitions by governments and sovereign wealth funds have made clear that for vital resources such as food, some governments lack faith in market-based allocation mechanisms. In what follows, we take the perspective of the corporation that operates within an environment characterized by the resource nexus.

The Resource Nexus as Environment

> *"Until recently, the planet was a large world in which human activities and their effects were neatly compartmentalized within nations, within sectors (energy, agriculture, trade), and within broad areas of concern (environment, economics, social). The compartments have begun to dissolve. This applies in particular to the various global 'crises' that have seized public concern, particularly over the past decade. These are not separate crises: an environmental crisis, a development crisis, an energy crisis. They are all one."*

Perhaps surprisingly, this quote dates back over 30 years (Brundtland and WCED, 1987). Since then these trends have only magnified. The deep interdependence among natural source resources and the techno-economic, market, and socio-political systems that have been built within our increasingly fragile (sink) ecosystems, creates significant challenges for organizations that operate within the resource nexus (Allouche et al., 2015). Jeremy Oppenheim, director of McKinsey & Company's Sustainability and Resource Productivity Practice stated that "the world is heading for an era of much higher, more volatile resource prices and much greater correlation across systems that used to be separate from each other" (Xynteo, 2012,

p. 13). While the higher prices are currently not materializing, the correlation across systems surely remains a focal challenge due to the volatility that precipitates.

In this context, we revisit the familiar terminology of dynamism, complexity, and munificence to describe the environment. While these familiar concepts are ordinarily captured by industry characteristics (volatility, concentration, growth), our framing significantly expands their usefulness by explicitly thinking about the meaning of dynamism, complexity, and munificence in the context of not only market, but also source and sink resources, and the techno-economic and socio-political dimensions. Table 2 provides a synoptic overview.

McArthur and Nystrom (1991) explain that *dynamism* pertains to the degree of market instability over time and turbulence caused by interconnectedness between organizations. More generally, dynamism refers to change that is hard to predict and that heightens uncertainty (Dess and Beard, 1984). Environmental dynamism is in most empirical research related to the unpredictability of demand, while unpredictability of competitor action, government action, or even technological evolution are less pronounced. Anderson and Tushman say that organizational environments "consist of inter-organizational niches, institutional factors and intra-industry structures" but are silent about the natural environment (2001, p. 703). Lee et al. (2012) speak of the "age of interdependence", while Scott et al. (2015, p. 23) suggest that uncertainty associated with dynamism can be attenuated by better understanding the "inter-dependence and inter-connectedness of social and bio-physical systems".

Uncertainty exists at the techno-economic level about which technologies will be economically viable and ecologically sustainable, while at the same time we need to consider whether viable extraction locations will be socio-politically acceptable. Such notions of dynamism and uncertainty typically remain out of the purview of management scholars or when they are considered they are presumed to have similar effects. Yet most of the strategies typically associated with dynamic (or complex) environments are meant to increase control over specific actors. Such dyadic actor-actor strategies are not very effective in dealing with events that transcend human agency. Specifically at the sink level, force majeure and the lack of deep understanding of how ecosystems interact and are affected by externalities such as greenhouse gasses in the atmosphere add to the uncertainty for organizational decision-makers. The truth of the matter is that even after decades of research, at this stage we still know quite little about how transgressions of "planetary boundaries" will affect other planet-wide ecosystems.

Complexity describes the degree of heterogeneity and the dispersion of organizational activities and is commonly captured by various concentration measures or specialization of product lines (McArthur and Nystrom, 1991). An organization's environment is more complex to the extent that it must keep track of heterogeneous actors which have a range of activities, linkages, and interactions outside its boundaries (Dess & Beard, 1984; Anderson & Tushman, 2001). The nexus brings many more heterogeneous actors that rely on and activities that require the same natural resources, into the fold which makes monitoring significantly more challenging. Complexity is also evident in the existence of the different dimensions of scarcity. Allouche et al. (2015, p. 616) pointed out that "what could be seen as an international political economy issue linked to unequal access has been framed as having an economic and technological solution". Others fear the likelihood of emergent resource-driven conflicts which could "escalate into socio-economic breakdowns with subsequent interruptions of supply chains for materials", especially in fragile states (Bleischwitz et al., 2014, p. 11).

At the socio-political level, Scott et al. (2015) state that complexity is evident in rules of use: 1) allocation rules determine criteria to allocate water for industry, irrigation, and water supply, 2) coordination rules define distribution criteria for funding and monitoring quality standards, 3) equity rules are norms about fair distribution (of NR, grants) between rural and urban communities, and 4) organizational rules are the formal rules in the public sector and are indicative of discretion allowed by distinct departments. Yet Sir David King argues that "the organization of governments into ministries and universities into departments perpetuates siloed thinking" such that more holistic nexus approaches are unlikely (Xynteo, 2012, p. 22). Finally, sink complexity is evident in our lack of knowledge about the importance of the distinct elements that make up a sink and critically influence its essential ecosystem functions, while monitoring ecosystem evolution and gathering data that are both reliable and affordable add another layer of complexity.

Table 2: The Nexus Environment

	Nexus Dynamism	Nexus Complexity	Nexus Munificence
Source NR	Nexus is unstable and unpredictable due to NR interdependence	Quantity of NR in the nexus, multi-functionality of NR, high monitoring costs	Actual NR stocks are unknown and known reserves are often private information/
Techno-economic	Uncertainty as to which technologies will be feasible and sustainable	Heterogeneity and the dispersion of organizations' activities	New technology can make NR accessible at acceptable economic cost
Market	Instability due to organizational interdependence, variable demand growth	Heterogeneous competition in NR markets, concentration of inputs	Hidden stocks suggest scarcity is not transparent in prices
Socio-political	Political co-dependence to make transnational decisions re NR	Allocation, coordination, equity, and organizational rules	Local and global sufficiency are distinct problems, conflicts can emerge
Sink NR	Force Majeure, NR nexus interdependence	Importance of distinct elements, ecosystem functions, and monitoring difficulties	Evolving capacity of biomes to absorb externalities affects growth potential

Finally, *munificence* typically refers to the capacity of an environment to support growth (Dess and Beard, 1984) and is commonly measured by growth of sales, employment, price-cost margin and so on (McArthur and Nystrom, 1991). At the source level, "scarcity cannot be measured objectively" (Andrews-Speed et al., 2012, p. 4). This explains why the 2012 WEF survey reported resource scarcity as the trend which courted the most controversy in terms of the extent to which it represented an over- or under-estimation in public perception. Predictions on the availability of some source resources sometimes vary by an order of magnitude (e.g. phosphorous: from 40 to 300-400 years (Grantham, 2012). Reports published between 2008 and 2013 share the perspective that demand growth for major resources would continually rise in the next few decades (e.g. Lee et al., 2012) but the slowdown of the Chinese economy has depressed both prices and demand. Thus, even industry experts are largely unable to correctly assess demand growth and possible scarcity in the short run (while long term trends might arguably be better predicted). This essentially means that an assessment of past munificence provides a very poor indication of future munificence and confirms that price movements are poor strategy guides (Alonso et al., 2007). This immediately suggests that market prices are not very reliable indicators of actual scarcity (Norgaard, 1990).

At the techno-economic level, munificence is determined by the ability of current and new technologies to extract source resources at an economically affordable price. Socio-politically, the issue of localness versus globalness plays a critical part in understanding munificence. While a source resource may be plentiful in one region, shortages elsewhere may appear. Six of the nine named planetary boundaries are aggregates from local data, and these aggregates could obfuscate regional abundance and scarcity (Rockström et al., 2009). E.g. African v American farming is very different so that 'glocal policies' around nitrogen, potash, and especially phosphorous are needed. While a global approach to managing the availability of especially phosphorous would be beneficial, the local implementation should lead to restraint in the USA and heavier use in Africa. Finally, the capacity of sink resources to sustain growth and further industrialization is under threat, especially when it comes to greenhouse gasses' effects on the climate (IPCC, 2014).

The interaction of these three environmental conditions creates a situation in which uncertainty is pervasive. The reality of the situation is such that the ever growing complexity of natural resource systems has largely outpaced our ability to exert control over them. As a result, although source resources balance at an aggregate supply and demand level, individual cases of resource scarcity are inevitable in temporally and spatially discrete contexts. Additionally, the effects on sink resources are quite often unpredictable as the below example makes clear.

Fuel for food: Why nexus challenges appear beyond (managerial) control

International policy creates heterogeneous competition for land and allocation uncertainty

The introduction of the biofuel mandates regarding the transportation fuel mix in the EU and the US has as a primary objective to reduce reliance on fossil fuels, both for strategic and environmental reasons. This firmly established a linkage between the food and the energy resource systems (with their own frames). The IEA requirements to ramp up biofuel production clashed with FAO's need for feed stock production on the supply side, creating a shortage of suitable soil with multiple effects.

Demographic shifts create price spikes and social unrest
This coincided with the increase in wealth of the BRIC countries during the previous decade which resulted in greater consumption of grain-fed dairy products, especially meat. Note that 47% of US land is used for agriculture, 70% of which is used to raise cattle (mainly cows) and grow the crops that these animals eat. Less than 1% is actually used to grow fruit, vegetables, and nuts for human consumption (DiCaprio, 2016). Reduced food reserves and the additional demand for feed-stocks to satisfy biofuel targets, changed the behaviour of global food markets which culminated in

the food price spike in 2008, i.e. doubling of maize, rapeseed and soybeans, tripling of wheat and quintupling of rice prices. It was claimed that the biofuel mandates resulted in food shortages and pushed between 30 to 100 M people into poverty with food riots reported in Haiti, Egypt and Bangladesh. This was despite the drivers for the event originating in seemingly unconnected regions.

Turning sink into source resources creates possible negative-sum trade-offs The Indirect Land Use Change (iLUC) debate focuses on how land that was previously designated as pure sink resource (biodiversity, carbon storage in forests), is converted into productive food crop land because former food crop land is being diverted to grow energy crops. This results in reduced feedstock availability and an increase in the price of food commodities (*substitution risk*).

Where bioenergy cropping occurs on land previously used for food, feed or fibre production, it displaces the previous production of food, feed or fibre. As demand for displaced production remains, it must be produced elsewhere, which might result in converting other land (and releasing carbon emissions) to produce the requisite amounts of food, feed, or fibre. These emissions from indirect land use changes are effectively caused by bio-energy production displacing food production and can, in the net balance, negate any positive effects of replacing fossil fuels. Carbon stocks in the top metre of wetlands stand at 679 tC / ha and forest 151 to 404 tC/ha– a substantial proportion of which stands to be released if converted for cultivation.

Additionally, the expansion of land for agricultural food commodities and bio-energy feed-stocks results in the loss of ecosystem and biodiversity services and carbon sinks. For instance, during the forest fires in Indonesia, lit to facilitate the further expansion of palm oil production, the fires alone push as much CO2 in the atmosphere as the entire USA. They also virtually destroyed the last place on earth where tigers, elephants, rhinos and orang-utans cohabited in the wild (DiCaprio, 2016). Many of the biomass assessments propose replacing land with plantations for forest growth, yet these typically do not have the same biodiversity and carbon storage benefits as primary land. Reduced biodiversity is also considered to impact on ecosystem resilience, i.e. the ability for ecosystems to resist environmental pressures. It is thought that lower biodiversity leads to increased likelihood of abrupt shifts in ecosystem states - though the relationship is not yet clearly understood.

Managing the Nexus

"Effectively and efficiently managing resources within a firm's given environmental context, ultimately determines the amount of value the firm generates and maintains" (Sirmon et al., 2007, p. 274). As such it is no surprise that an increase in uncertainty regarding critical resources is accompanied by higher organizational exit rates (Anderson and Tushman, 2001). Thus, resource-related uncertainty will make it harder for a manager to steer their organization in the right direction.

A primary concern for managers operating in the resource nexus is decision response uncertainty, which can be understood as the inability to predict how a chosen response will affect the nexus (Miller and Shamsie, 1999; Milliken, 1987). Given the lack of scientific knowledge about the exact interdependencies among various natural source resources, their extraction, and sink resources, decision response uncertainty is less an idiosyncratic issue of decision-maker ignorance than one of genuine unknowns. One normative solution would be for managers to abide by the precautionary principles and not engage in actions that might cause environmental harm unless if they prove that no harm can be reasonably expected. While this approach is often favored by environmentalists, it might impose undue limitations on innovation and leave local entrepreneurs that are working in difficult natural ecosystems with not much alternatives. Perhaps a better strategy is one of small scale experimentation with close measuring of the potential negative externalities. The risk of such an approach is that externalities emerge in a non-linear way, in that they can remain rather insignificant until a threshold is passed after which they become irreversible.

A secondary problem is that even if we had perfect information into how a specific intervention would affect associated ecosystems in the nexus, it is unlikely that many Pareto improvements are easily available. Given that many choices are likely to be associated with damage done to either a human minority or to fauna and flora, the absence of "uncontested actions" requires either a negotiation between the powerful actor and the relevant stakeholders, which risks perpetuating power divisions and social inequality, or a dominant, yet unenforceable normative morality (see also Foran, 2015). Given that such a morality is unlikely to be shared by different interest groups, the nexus concept is susceptible to disregarding the powerless in favor of the powerful. While this could be a preferred strategy from a corporate perspective, it risks alienating societal stakeholders and can as such cause social disruption if stakeholder's needs become more urgent and find a way to seize more power (Mitchell et al., 1997). How should corporate decision-makers then deal with the problems imposed by the resource nexus, i.e. how to operate in an environment characterized by high complexity, uncertainty, and ambiguity? While the empirical evidence on corporate responses to the resource nexus is slim, we present three largely complementary strategies that provide ways to manage uncertainty in dynamic, complex, and non-munificent natural resource environments.

Developing Anti-Fragility

Already from the late eighties, firms and scholars have worried about how to integrate organization-centric strategic planning and environment-centric issue management (Camillus and Datta, 1991). Yet how managers are expected to cope with an issue as complex as the resource nexus has largely escaped scholarly attention. In his 2012 book, Nassim Taleb defines antifragility as the capacity to gain from disorder, randomness, stressors, or uncertainty. He suggests that every organic system needs some exposure to external variability else its immunity is weakened. For organizations we can think about anti-fragility as the ability to outperform rivals in uncertain environments characterized by high dynamism and complexity, and low munificence. Note that this is difference from resilience which can be understood as a measure of: (a) how much change a system can undergo while retaining the same control and returning to its original state, (b) the self-organizing capacity of the system, and (c) the learning and adaptive ability of a system (Scott et al., 2015). While a resilient firm may thus weather the storm, an antifragile one will become better after the storm than it was before.

Some of the key strategies Taleb (2012) advocates are tinkering or bricolage, failing fast with small losses and using heuristics over theory. These reflect an entrepreneurial risk-seeking attitude. Relatedly, Boisot and Child (1999) have suggested that firms in highly uncertain environments should absorb complexity by developing structural variety, fostering interpersonal connectivity, and pursuing multiple, even contradictory, goals and strategies hence generating behavioral plasticity. One way of doing this is by considering both internal and external stakeholder perspectives which helps decision-makers shield from overly simplistic interpretations of the environment (Ashmos et al., 2000). On top of that decentralized decision-making has also been found to be conducive to adapting to environmental complexity. Newtonian organizations tend to reduce complexity instead of absorbing it and are characterized by clear lines of authority, predefined roles and accountabilities, and if-then incentive structures are less likely to cope well in uncertain environments such as the resource nexus. (Ashmos et al., 2000).

In organizational ecology, generalists have higher likelihood of survival than specialists in fluctuating environments and the reverse is true when the environment is relatively stable (Hannan and Freeman, 1977). While specialization generally leads to efficiency gains, firms operating in the resource nexus face both high demand and supply volatility, as well as an insecure regulatory framework and increasingly pressing sink resource limitations. Especially in uncertain environments with low munificence, resources as real options might provide firms with necessary capabilities to act quickly to opportunities and threats. In these environments developing resources internally is recommended while divesting is considered to be risky (Sirmon et al., 2007).

Innovation: Boosting Flexibility

Ahmed et al. (1996, p. 562) stated that in the coming decades "flexibility and responsiveness built upon a solid foundation of product quality, performance, reliability, service, and cost offer promise as platforms of competitive advantage". Firms active in the resource nexus will have to imbricate these dynamic capabilities with their core competences as companies like H&M and Zara have successfully done in response to more volatile consumer preferences. Yet, increasingly short lead times and just-in-time delivery systems are notoriously fragile as even minor shocks in the supply network can have wide-ranging ripple effects (Cobb, 2013). To prevent these negative shockwaves, functional redundancy - what Taleb calls "degeneracy" – needs to be built into supply networks so that multiple suppliers can flexibly meet the requirements if one fails. In the resource nexus, this means geographically and organizationally diverse supply networks that are unlikely to be exposed to the same natural environmental effects (disasters) at the same time.

When it comes to product design, flexibility requires the ability to adapt either the input or the timing of the input acquisition decision in response to nexus issues. During the period of rare earth shortages and steep price spikes (Hayes-Labruto et al., 2013), Vestas altered it wind turbine design to enable it to postpone the purchase of dysprosium until the very last minute. This allowed the company to find out if prices would drop. The design was changed in such a way that in case prices remained prohibitively high, an alternative system that did not require the scarce resource could be deployed as well (personal communications). While such design choices lowered operational efficiency, they were considered the lesser of two evils in volatile and opaque natural resource markets.

Another piece of the puzzle relates not to the design itself but to how design changes can affect the markets for disposal. Gavin Neath from Unilever cautioned that "technology itself is often not enough. The behaviour change piece can be harder, and a lot more expensive" (Xynteo, 2012, p. 19). This realization suggests that organizations in the resource nexus need to spend extra effort streamlining operations in such a way that sales, marketing, design, logistics, and purchasing collaborate effectively and efficiently. On top of that, departments such as finance and legal, which often stay siloed in organizational structure, should be included in cross-departmental teams to better manage the environmental uncertainty. For instance, Dreyer and Grønhaug (2012) show that input, production, and financial flexibility all contribute to the likelihood of survival in a longitudinal study of the Norwegian fishing industry. Similarly, White and Hanmer-Lloyd (1999) argued that for purchasing departments to live up to their strategic potential, the CEO needs to be actively involved because competitiveness in output markets increasingly relies on the firm's ability to behave more flexible than its competitors in input markets.

Openness and Collective Action

One of the most fundamental things organizations involved in the resource nexus can do for their survival and success is to recognize their own limitations when it comes to tackling the challenge at hand. We submit that nexus problems are often too "wicked" to be solved by a single actor because they transcend the core capabilities of any single actor. Almost 30 years ago, Carney (1987, p. 341) stipulated that "collective action is a necessary response to environmental turbulence" and seldom has this rung more true than when it comes to the resource nexus. Looking at the problem of water scarcity in developing nations, the Asian Development Bank has stated improving the supply side infrastructure, addressing demand-side factors including water pricing, strengthening governance, and building new institutions (ADB, 2013, p. vi-vii) are all required to generate credible solutions. No single organization has the core competence to do all these things at once and thus symbiotic collective action is required. As a form of communal adaptation, symbiosis captures the agreements between actors of different types that "make dissimilar demands on the environment… [and as such] may supplement the efforts of one another" (Astley and Fombrun, 1983, p. 573).

Additionally, commensalism is a form of communal adaptation that arises between similar actors that make overlapping and competitive demands on the environment (Astley and Fombrun, 1983). While commensalism can be frowned upon from an anti-trust perspective, it is good to remember that the word competition hails from the Latin 'competare' which originally means, 'to get fit at the same time'. To deal with the negative externalities of mining oil sands, Shell and six other large oil sand minders set up the "Oil Sands Tailing Consortium" that promotes and shares research on reducing water usage and lowering the risks of land and water contamination. Peter Voser, Shell's CEO said that "we need understanding beyond our own areas. Collaboration is critical to getting action across the stress nexus" (Xynteo, 2012, p. 33). Both forms of communal adaptation require a certain openness that might not come easily to many corporations. Yet Scott et al. suggest that "systems that respond effectively to uncertainty are usually supported by flows of information on biophysical and institutional processes" (2015, p. 24).

At a very practical level, collaboration between governments, companies, NGOs, and communities is required to improve the data availability on natural resources. Many natural resource markets remain opaque which makes accurate predictions of future global supply and local areas where shortages could appear very difficult. Bleischwitz et al. (2014) and conclude that one necessary way forward is the establishment of an international data hub on the global resource nexus. Such a datahub should merry the corporate desire for maintaining secrecy regarding their most valuable assets with the political and societal necessity of knowing (national and ideally local) aggregate quantities. Modern cryptography and secure online storage can play a role in this collective knowledge challenge.

Lead by Example

The Novelis case provides a great example of an organization that is working towards reducing its negative impact on all aspects of the resource nexus, by doing much of what we suggested above. First, their internal and external organization become way more complex since they embarked on their sustainability journey in 2011. This higher complexity is an absorption response to the increasing environmental complexity and thus enhances their anti-fragility.

In 2005, Novelis was split of of Alcan, creating the first global downstream aluminum company without any mining assets (Clinton and March, 2015). By 2011 the company was under new ownership and management and CEO Phil Martens set out to close the aluminum loop, reducing Novelis' use of virgin aluminum to less than 20%. Martens believed that "the challenges associated with global sustainability – energy, climate, biodiversity, poverty, and inequality – would soon become central to any company's corporate strategy, especially in material- and energy-intensive industries" (Clinton and March, 2015, p. 26). As such, the CEO indicated awareness of the resource nexus and the interdependence between different elements that would affect his organization. An ambitious goal of 80% recycled content (up from 33% in 2011) was set which would require a complete overhaul of product portfolio and design, new R&D for a new aluminum alloy, and a change in customer relations to ensure end-of-life products returned to the company. Such a radical business model innovation requires internal restructuring and streamlining of functions and departments in line with new goals and objectives as discussed under "boosting flexibility"

In the process the company made some radical changes such as dropping products that required mainly primary aluminum, diversifying the scrap stream, and investing heavily in R&D and global recycling capacity. They also left the US National Association of Manufacturers to be able to take a more proactive stand on climate change. In addition, they actively engaged with policymakers to educate stakeholders and build infrastructure for post-consumer recycling, and opened up the supply chain by forming "unconventional partnerships with cooperatives, community groups and small scrap dealers" (Clinton and March, 2015, p. 28). In response to concerns of the three large can makers who feared they would be held hostage by a single company providing a closed-loop can, the company "offered to assist other companies to certify high-recycled content sheet" to make cans (p. 29). Hence not only did they engage in symbiotic and commensalistic relationships with unconventional partners and competitors, they also made a stand by leaving other relationships that would have held back their ambitions.

While recycling aluminum is of course easier than recycling complex end-user products such as electronics, the example presented here shows how far a company can go to achieve sustainability ends. Given the urgency of the problems we are facing, especially at the level of the sink resources and their diminishing capacity to absorb the externalities caused by industrial production, we sincerely hope that many other organizations will follow the Novelis example, and start putting the resource nexus at the center of business strategy.

Conclusion

With some foresight and political collaboration, mankind need never reach absolute scarcity of any source resource assuming developments in technology combined with a sufficient supply of energy. However, such processes are bound by the capacity for sink resources to assimilate anthropological waste from economic development – and as such these capacities or environmental limits are the true resource constraints of the modern agenda. “Given that the overall costs of inaction are generally higher than those of pro-active adaptation” (Hoff, 2011, p. 12), the task of business and government in the long run is obvious, yet how we get there is significantly less clear. It is paramount that business recognises this collective need and play their part, both for their own sake and for the wider community in which they operate.

In this chapter, we presented the resource nexus, the latest frame for scarcity thinking. One of the most popular subframes of that frame looks at the nexus from a water, energy, and food perspective: “The WEF Nexus, in other words, is a pivotal concept for scientific research and a policy tool that allows for operationalization of links between sets of two resources (water-food, food-energy, water-energy) building up to a triple nexus or triad approach to adaptive management” (Scott et al., 2015, p. 33). We have gone a step further by not only looking at the biophysical systems that underlie the nexus, but also the human ones. We postulated that the availability of natural resources is intrinsically limited by source and sink resource capacities, and affected by techno-economic, market, and socio-political realities. In addition, we believe that the ever-growing complexity of the modern resource system caused by increased resource utilization, physical and operational resource interdependencies, coupling of commodity markets globally, and the increased levels of world trade is exacerbated by the interactions between environmental sink resources. This could lead to thresholds being crossed before we have had the chance to develop human systems capable of monitoring and managing environmental systems. Arguably, this has already happened.

So far, these evolutions have outpaced our shared human capacity to understand and let alone prevent the great risks associated with greater interdependence (the nexus). We can hold out hope for human ingenuity and the potential this has to plot the trajectory of the planetary biome in the Anthropocene, though a certain level of urgency is needed if the challenges faced are to be prevented from becoming crises. As such, there is considerable room for improvement of the business-as-usual approach to managing natural resources. We hope this chapter and the other ones in this book provide some inspiration for those renegade optimists and critical thinkers, to deploy their collective imagination to the most worthy of causes.

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