An Evolutionary theory and supply network perspective on manufacturing firms' capabilities development in water scarcity management

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Abstract

The notion of water scarcity risks has become a crucial element in the firm's sustainable development. Increasing number of businesses understanding the criticality of water availability adjust their corporate social responsibility and environmental strategies.

This study explores the firm's adaptation and learning processes to the resource availability levels through the Evolutionary theory (EvT) perspective. The study suggests a novel supply chain capabilities development process resulting in the proposition of firm types and configurational patterns according to Darwinian principles.

Keywords: Evolutionary theory, supply chain sustainability, mitigation capabilities for water scarcity

Introduction

Sustainability is firmly on the agenda for leading companies and there is growing recognition that it is a primary driver for strategic product and business model innovation. At the same time, sustainable development has become a dominant topic in different industry sectors and has been addressed through various studies (Mulder and Van Den Bergh, 2001) in which the main focus is on the interaction of business strategies with the biophysical environment. One of the elements of such biophysical environments is portrayed by natural resources such as water. Therefore, changing levels of natural resource availability due to an imbalance in resource supply and demand that in turn is influenced by technological (technology increases the availability of all goods and resources), environmental (climate change, biodiversity loss), societal (population increase, globalisation, urbanisation), political (competition to acquire resources, corruption by government officials responsible for resource management, the mix of

private vs. public good outputs produced by a nation's natural resources, like forests, affected by the political system), and economic (consumption patterns, industrialisation) changes, increases the uncertainty levels in the business environment. This situation forces firms to mitigate and adapt (Mulder and Van Den Bergh, 2001) to these environmental changes developing effective supply chain (SC) approaches under vigorous business strategies (Morash, 2001*)*.

Application of natural resource scarcity in the SC management domain is not widely explored from the perspective of evolutionary theory. Although, evolutionary theory (EvT) has been applied to organisational studies, there is still limited evidence suggesting an application of EvT to the Operations Management field. Specifically, capabilities development processes for SCs affected by water scarcity is not widely explored. This research makes an attempt to bridge this gap by proposing an exploratory framework. The framework was tested through exploratory case studies to propose the directions for future research.

Literature review

The Darwinian model of evolution has been widely used in various disciplines, e.g. linguistics, anthropology, and economics (Betton and Dess, 1985). Applying Darwinian principles, scholars have further formulated evolutionary accounts (Srai and Alinaghian, 2013) to explain phenomena on various levels. For instance, at the individual level Campel (1969) has proposed a generic application of the evolutionary model in the context of socio-cultural evolution. Work by Miller and Mintzberg (1984) has been applied at the organizational level, proposing survival mechanisms and natural selection of organisations in the business environment (Vale, 1980). At the industrial economy level, evolutionary theory examines the effect of global changes on organisational populations (Carroll and Hannan, 1989; Jacobides and Winter, 2005).

The main focus of current research is on the organisational level. One of the first studies that compares biological evolution with organisational evolution, developed by McKelvey and Aldrich (1983), has identified that organisations must develop evolutionary significant attributes that will enhance their ability to survive in changing environments. Here, the environment is defined by bio-physical, political, economic, legal, cultural, and technological forces (Hall, 1982 in McKelvey and Aldrich 1983 p. 111) to which the firm has to adapt. Adapting to the changing environment, the organisation undergoes a number of evolutionary processes:

1. The principle of variation is represented by any kind of change (McKelvey and Aldrich, 1983) or creation of new organisational forms (Srai and Alinaghian, 2013; Van de Ven and Poole, 1995);
2. The principle of natural selection is employed to eliminate certain types of variations or characteristics in organisations that are less beneficial for acquiring finite resources (McKelvey and Aldrich, 1983);
3. The principle of retention and diffusion includes mechanisms that perpetuate and maintain selected beneficial variations or organisational forms (McKelvey and Aldrich, 1983).

In population ecology, the environment is considered "a major force shaping organisational change" (p. 56, Aldrich, 2008). Following Darwinian principles, selection occurs due to environmental pressures. As such, and transposing this line of reasoning to business realm, environments influence organisations through a process of making resources available or unavailable and affecting efficacy in attaining these resources.

This study is focused on the firm's environmental aspects that are determined by biophysical constraints expressed in terms of natural resource scarcity such as water.

Natural resource scarcity presents imbalance in resource supply and demand (FAO, 2012; FAO, 2013). However, water scarcity is driven by a combination of various factors including climatic, geological, socio-economic, and political (Yatskovskaya and Srai, 2017). All these elements make water scarcity a dynamic problem adapting to which companies undergo actionable knowledge development process for subsequent SC capabilities building phase

Method

Framework development

The study employs an extensive literature review process covering three major literature domains - natural resource scarcity, evolutionary theory, and sustainable supply networks design - to propose a research hypothesis development framework. The outcomes of the review suggest that within a water scarcity context, the organisational environment can be considered as a pool of information (Aldrich, 2008) about water availability that the company collects and interprets in order to further search for mitigation capabilities by employing various resource flows, e.g. technologies, polices, assets, labour, etc. (Yatskovskaya et al., 2017).

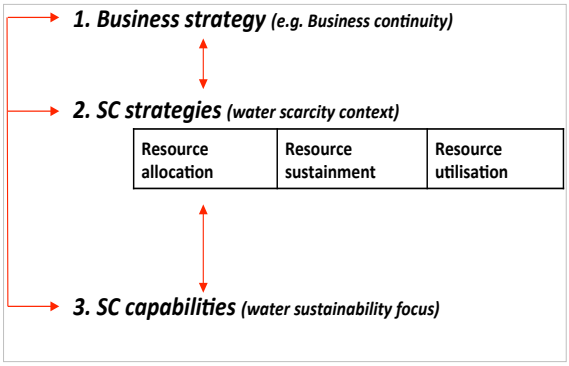
The current study suggests that by developing both adaptive behaviour and learning, the firm undergoes two consecutive processes: (i) *actionable knowledge* generation, driven by a necessity to understand or learn about the changing environment (based on information flows) (Antonacopoulou, 2006); and (ii) *mitigation capabilities* development (based on resource flows) (Yatskovskaya and Srai, 2017) brought about by the necessity to survive under environmental constraints. Each of these stages contains three sub-stages that follow an evolutionary process in their development, involving variation, selection, and retention.

- At the first stage, "variation", the organisation pulls together various water availability information sources and attempts to identify possible methods and variables to generation of accurate projections.
- At the second stage, "selection", the firm seeks to eliminate the least accurate indicators for water availability evaluation and projection.
- At the last stage, "retention", the organisation employs either readily available identified indicators, generated by the tools selected at stage two, or self-generated indicators, based on pre-selected datasets, methods, and variables. Based on the indicators, the firm develops an actionable knowledge about current or future water availability in the form of impact. At this stage, the produced indicators can also be rejected due to their inability to accurately identify water availability levels, then the process repeats. In case of success, generated actionable knowledge, based on the selected indicators, is further transmitted to other functional units of organisation to support a design of water stress informed business strategies and abreast SC strategies.

These SC strategies are further supported by the development of specific water stress capabilities.

The ability to acquire and interpret information about the environment in which the firm operates, helps the company to further generate mitigation responses in the form of new strategies and subsequent capabilities. Based on this acquired actionable knowledge, the firm develops a set of capabilities to respond to certain risks from water scarcity. The framework of this capabilities to mitigate the scarcity of water are depicted in Figure 1.

Figure 1–Water scarcity mitigation capabilities framework



SC capabilities here (Figure 1) represent one of the building blocks connecting business strategy and SC strategy that leads to SC performance development (Morash, 2001). Water stress mitigation strategies take the form of three major approaches: resource allocation, resource sustainment, and resource utilisation (Yatskovskaya and Srai, 2017). These strategies, in turn, are supported by specific water stress mitigation capabilities. SC capabilities represent "tangible or intangible processes that are firm specific" (Srai et al., 2013, p.595). Notably, capabilities can also be distinguished as static or dynamic. *Static capabilities* are the processes a company develops over time including water reduction, water recycling, reclamation, emissions management, etc. (Closs et al., 2011; Sarni, 2011; Srai et al., 2013),.

Dynamic capabilities are strategic routines, processes, product developments, and new supplier integration practice developments used to adapt to constantly changing environments, and which lead to long or short-term sustainable competitive advantages (Beske et al., 2014; Brusset and Teller, 2016; Lee et al., 2014; Teece, 2007). Examples of dynamic capabilities within the water availability context are, as instance, capital investments in technology for water stress elimination, or the adoption of water neutral approaches. (Babin and Nikholson, 2011; Closs et al., 2011; Kleindorfer et al., 2005).

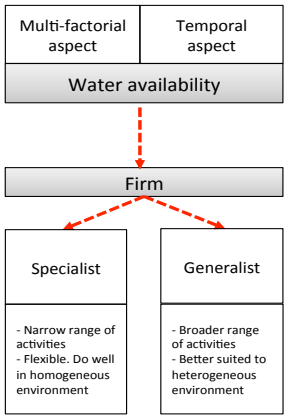
This study adopts an evolutionary concept of the environment in the form of resource flows, i.e. water availability, which the firm examines in order to develop water stress mitigation capabilities. The current work proposes that the development of these mitigation capabilities should also follow a three-step evolutionary process (Figure 1), explained above:

- First stage, "variation": the firm obtains information about existing strategic capabilities to mitigate water scarcity. At this stage scoping of possible available practices for certain levels of water scarcity at the given location under prevailing environmental, political, economic, and technological conditions takes place.
- Second stage, "selection": the firm refines its water stress mitigation capabilities eliminating dynamic or static capabilities that fit the least for the defined period of time.
- Third stage, "retention": the firm implements selected mitigation strategies in its production process design, product design, or along its value chain. If the selected mitigation capabilities work well, the firm continues applying them. Alternatively, the company modifies these capabilities to better fit to the changing environment.

Based on this capabilities classification and through the lens of the EvT perspective, the research proposes two firm types, specialist and generalist, suggesting that each type would be prone to developing specific capabilities resulting in certain SC configurational patterns, mimicking a natural system (Figure 2). This classification of the firm types is

rooted to the concept of the environmental niche. Firms develop and adopt existing mitigation strategies in order to gain a better fit within the environmental niche (McKelvey and Aldrich, 1983; Aldrich, 2008).

Figure 2 – Firm types



Specialist firms engage only in a narrow range of activities and do well in a specific state of the environment, when it is stable and homogeneous, which is presented with slight deviations from a previous state. Specialists firms are more fit than generalists within a narrow range of the environmental change where they compete without maintaining extra capacity to meet a different state of the environment (Aldrich, 2008).

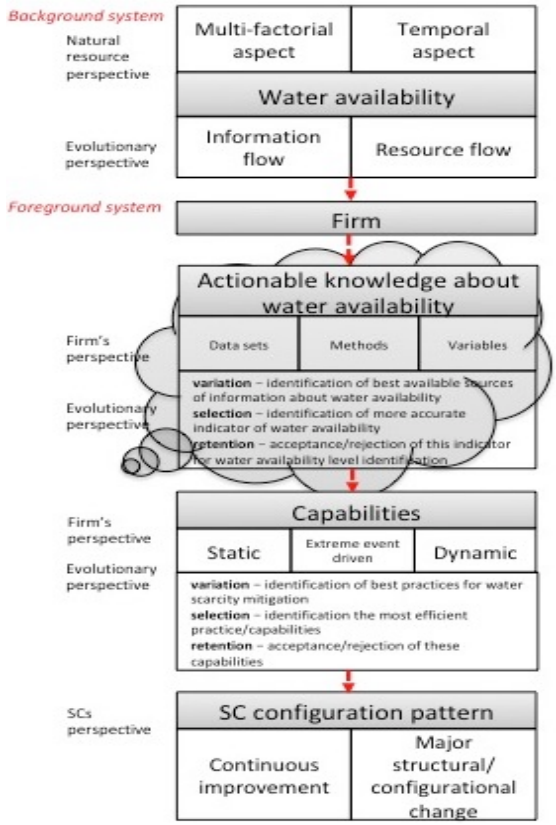
Generalist firms engage in a broader range of activities and do less well within a stable and certain state of the environment. Thus, generalists spread their fitness over a large number of environmental states and have a better fit to unstable and heterogeneous environments and cannot optimally adapt to any single environmental state (Hannan and Freeman, 1977). This type of firm has to maintain an excessive capacity for anticipation of future needs in order to take advantage of resources that become more or less available (Aldrich, 2008). In stable environments "specialists outcompete generalists over the range of outcomes to which they have specialised" (Hannan and Freeman, 1977, p.950) due to the fixed level of fitness assumption. Conversely, "if the environment is only occasionally within the interval" (Aldrich, 2008, p.114) generalists will outcompete specialists. Generalists will do well when the differences between environmental states, even if occurring frequently, are small such that an extra capacity is not a burden. However, when the difference between different states of the environment is great, it is likely specialists will be selected. This is also the case when the environment is extremely unstable (Aldrich, 2008).

This study proposes an application of the concept of firm fitness to the context of a water-constrained environment. *Specialist firms* are organisations that have abilities to quickly adapt to the changing environment, developing or maintaining capabilities specifically for water stress mitigation. This type of firm can be generally presented by specialised companies that have a capacity to quickly switch or improve their production processes towards water efficiency. Companies (suppliers) that produce certain components or products in water scarce regions could be identified as specialists in terms of their ability to adapt to water availability levels whilst maintaining production levels. *Generalists*, on the other hand, are firms that, understanding the importance of sustainability in their SCs, develop a capacity to build mitigation capabilities slowly over time. These capabilities might not be specifically developed around water scarcity mitigation but rather are generally focused on various aspects of sustainability. As a

result, these firms are not flexible to changes in environmental states. This type of firm is represented by organisations with a broad range of activities and spatially dispersed SCs. Consequently, generalists don't develop abilities to rapidly alter their production processes to become adept in water sustainability.

The research development process is depicted in the research framework (Figure 3). The proposed research hypothesis development framework is based on an evolutionary theory perspective, linking concepts of the environment as information and resource flows, and advocates an adaptation process development following three evolutionary stages for actionable knowledge and capabilities generation for two firm types.

Figure 3 – Research hypothesis development framework



Further, this framework was tested through exploratory case studies, based on which theoretical arguments were set to propose directions for future work.

Framework application

In order to test the proposed framework, two exploratory case studies were conducted. The case study approach was chosen due to the exploratory nature of the study. Selection of the exploratory case companies was determined according to the level of interest of the multinational organisations in tackling water scarcity problems in their global operations.

Our case study was informed by two large multinational organisations within the pharmaceutical, and food and beverage industry sectors, with wide supply networks and some manufacturing operations located in water-stressed regions. The analysed cases are focused on upstream supply chains.

Semi-structured interviews were conducted with the Senior Sustainability Manager and Global Sustainability Director, of each organisation. Due to a non-disclosure

agreement, the company names and the identity of the interviewees were kept anonymised. The interviews were arranged in several sessions with total duration of 6.5 hours. The data gathering was complemented with secondary sources, including companies' reports, sustainability disclosure reports, and news sources. The interviews were recorded and transcribed for subsequent analysis. Qualitative coding was used to analyse the interviews. Thematic analysis was used to identify relevant topics emerging from the data. Through two iterations of coding, the elements of the framework were refined. The results of the analysis are presented in the following section.

Analysis and discussion

During the exploratory case studies, the proposed framework testing took place. As a result, actionable knowledge building process and capabilities development process through the prism of Darwinian principles were analysed.

Conventionally, food, beverage, and semiconductor industries are associated with the development of water scarcity alleviation strategies due to their high-water intensity consumption (Sarni, 2011). Thus, one of the leading global beverage producers was chosen for an exploratory case study. The company has over 30 production sites and great number sourced agricultural commodities are located in the regions of high water stress. As a result, the company has established a well-defined proactive water sustainability agenda. The company is defined as specialist firm.

In order to track geographical water availability for a strategic overview the WRI Aqueduct tool[1] is primarily employed. In order to project water availability for operational purposes at the critical markets the firm collects the data from various publically available local data sources, including country/state water availability reports, weather patterns projections, and the rainfall tracking. Based on the analysis of the selected data sources the firm makes a decision for mitigation capabilities employment for the time horizon of 12-14 months. These publically available data sources scoping exercise is characterised by the variation stage, while on the selection stage elimination of unreliable or the datasets with insufficient data takes place. Based on the obtained information regarding water availability, the firm develops its actionable knowledge that is further used to build mitigation capabilities. For instance, for their suppliers located in the water scarce areas the company search for various water scarcity risks mitigation strategies such as "farming methodologies, different [crop] varietal selection…[to] create a resilience in the supply networks". If these strategies are inefficient in the region, the company looks for alternative suppliers. These confirms Evolutionary principle of variation and selection for capabilities building process. Retention of the selected water scarcity mitigation strategy occurs when company employs the selected strategy from year to year for the same location. The company stated that they have already started considering switching crops "in order to support crops …[that] are more climate change resilient", indicating the firm's proactive dynamic approach to water scarcity risks mitigation. The case study results show that the company continuously introduces structural changes in its SC structure that shapes the firm SC configurational pattern.

[1] WRI Aqueduct is a tool created by the World Resources Institute and is the first ever to provide customisable global maps of twelve indicators of water risk, ranging from water stress levels to drought intensity to threatened amphibian species.

For a second case a pharmaceutical organisation was selected. This choice of industry demonstrates that other sectors have also become increasingly affected by water scarcity problems. The selected pharmaceutical organisation is one the largest manufacturers in the pharma sector that has shown increased interest in tackling water scarcity issues. The company employs water scarcity mitigation strategies that are mainly reactive. Based on company's actionable knowledge and mitigation capabilities building processes the firm is categorised as a generalist.

Company evaluates physical water availability based on the publically available WRI tool, which it complements with WWF The Water Risk Filter. The combined data from both tools enable the firm to evaluate water scarcity risks cross all manufacturing and suppliers' locations. This illustrates the principle of variation. The principle of selection is shown when firm seeks to obtain more accurate indicators by adding its own weightings for each risk category. Based on this, firm eliminates the least affected locations focusing only at the sites and suppliers with high and extremely high-water stress risk. Occasionally the firm reviews and revaluates their results.

Based on the obtained actionable knowledge, the company further develops mitigation solutions. For example, when high water stress risk areas are identified or when raw material sourcing is failed, firm seeks for new contractual arrangements with multiple alternative suppliers instead of a single supplier. The firm builds mitigation capabilities that are mainly reactive and static. In order to support these suppliers, the firm conducts annual assessment programme. However, firm does not have an ability to influence their suppliers' water management practices: "… we actively encourage them [suppliers] to improve their water sustainability [practices]…instead of shutting down [manufacturing sites] as they wait for the monsoon …[but] that is still early days because we won't pay them to do that". These show variation and selection principles applied to water scarcity mitigation capabilities developed for the suppliers. The case study results show that the company continuously introduces improvements in its SC structure with regards to water sustainability.

Integrating findings across the two exploratory case studies, from the perspective of observed water stress mitigation capabilities, it is evidenced that specialist type firm, following evolutionary principles, develops dynamic capabilities which results in structural SC improvement. The generalist firm, on the other hand, is prone to develop static capabilities which lead to continuous improvement of firm's SCs.

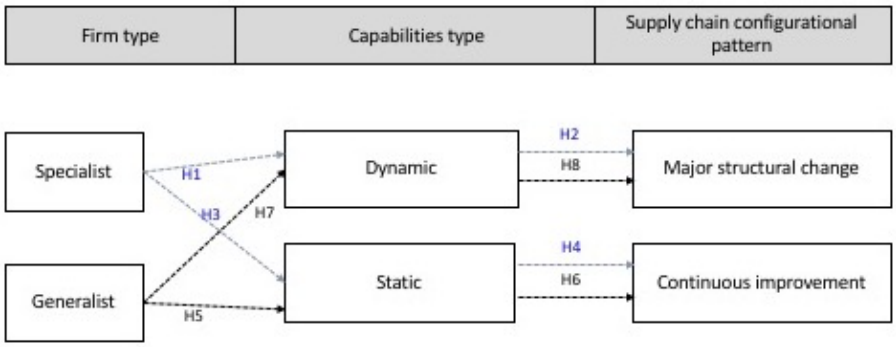
Conclusion

The current study extends Evolutionary Organisation Theory (Aldrich, 2008) to the resource scarcity domain, focusing on water: (i) to illustrate water a scarcity mitigation capabilities building process, (ii) to demonstrate application of the firm types application, and (iii) to propose the hypothesis for the future work.

Results from the two case studies illustrate actionable knowledge and capability development processes that follows evolutionary steps. The results suggest that companies of a certain type are more likely to adopt a particular type of water stress mitigation capability, while employed capabilities of a certain type are likely to result in a specific SC configurational pattern.

Observed findings from the literature and case study research allow the drawing up of eight hypothesis concerning the relationships between firms and capabilities type, and SCs configurational patterns (Figure 4) to be proposed.

Figure 4 – Hypothesis about SC configurational patterns



Specialist firms are organisations that quickly adapt to the changing environment, developing and maintaining capabilities specifically for water stress mitigation, such as quickly switching or improving their production processes towards greater water efficiency. This study suggests that:

H1: The specialist firm is likely to develop dynamic capabilities for water scarcity mitigation

Acquiring these capabilities, the specialist firm builds resilience to adapt to a constantly changing water constrained environment. Therefore:

H2: Developing dynamic capabilities, SCs of the specialist firm are likely to go through major structural changes e.g. relocation of manufacturing operations, dispersion of SCs, re-sizing of the manufacturing units

H3: When the specialist firm starts developing static capabilities, it transitions to the generalist firm

H4: A specialist firm that continually develops static capabilities, converts to a generalist firm that is likely to acquire a continuous improvement configurational pattern for its SCs

Generalist firms are companies that are building mitigation capabilities slowly over time, therefore this type of firm is not flexible and does not have abilities to quickly adapt their operations to more sustainable ones. Generally, these firms focus on various aspects of sustainability but not specifically on water.

H5: The generalist firm is likely to develop static capabilities in order to mitigate water scarcity risks

H6: Developing static capabilities, SCs of generalist firms are likely to go through continuous improvement e.g. lean, agile, leagile SCs

H7: When the generalist firm starts developing dynamic capabilities it acquires a new specialist form

H8=H2

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