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Asbjørn Karlsen, Henrik Brynthe Lund, Markus Steen

University of Vienna | Vienna University of Economics and Business | Austrian Academy of Sciences | University of Agder | Kiel University

Cluster absorptive capacity: Two types of intermediaries in technology upgrading of manufacturing clusters

Asbjørn Karlsen[^], Henrik Brynthe Lund[^], Markus Steen[*]

[^]*Department of Geography, Norwegian University of Science and Technology, Trondheim*

[*]*Department of Technology Management, SINTEF Digital, Trondheim*

Abstract

Specialized clusters are based on common knowledge resources and other positive externalities, but it is unclear how such resources develop over time. A case in point is how extra-cluster knowledge linkages are integrated into intra-cluster linkages by firms or other actors and subsequently shared with other cluster actors. To advance the understanding of cluster dynamics and renewal through knowledge exchange, the authors develop a refined conceptualization of cluster absorptive capacity by addressing the role of agency. Intermediaries link clusters to external knowledge sources and contribute to dissemination of knowledge among cluster firms, and the authors find this perspective relevant because manufacturing firms are facing rapid changes in technology platforms, such as those associated with 'Industry 4.0'. Additionally, the authors analyse processes of knowledge exchange and technology upgrading of two mature manufacturing clusters in Norway. The results show that the processes are supported by knowledge institutions and facilitated by cluster organizations in quite different ways. In the light of the theoretical discussions and findings from the two case studies, the authors propose a novel conceptual framework that combines two types of intermediaries and two types of absorptive capacities for investigating the role of non-firm actors in contrasting types of clusters.

Keywords: Cluster Dynamics, Absorptive Capacity, Extra-cluster Linkages, Intermediaries, Technology Upgrading, Industry 4.0

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1 Introduction

Few theoretical constructs in the economic geography and regional science literatures rival the cluster concept in terms of academic interest and popularity among policymakers (Porter 2000; Ebbekink and Langdijk, 2013; Trippl et al., 2015; Isaksen 2018). Scholars in the field typically assume that cluster firms effectively share knowledge between them via various localized knowledge spillover mechanisms (Audretsch and Feldman, 2004). Recent contributions to the cluster debate emphasize that cluster firms and organizations need to source extra-cluster knowledge and develop extra-regional linkages in order to stay competitive (Bathelt et al., 2004; Karlsen and Nordhus, 2011; Kesidou and Snyjders, 2012).

Extra-cluster knowledge inputs are especially important in times of rapid and comprehensive technological change. Recent technological development, especially in terms of manufacturing technologies, has been associated with the term Industry 4.0 (I4.0), which creates a momentum for discussing how cluster firms should engage with technological upgrading. I4.0 technologies are predicted to have significant implications for the organization of production both within firms (Schwab, 2016) and in value chains and networks. For firms facing accelerated technological change, it appears urgent to develop organizational capabilities to implement these new technologies. Capabilities for technology upgrading have largely been analysed on the individual firm level (Crescenzi and Gagliardi, 2018), while less attention has been paid to the cluster level.

In their seminal contribution, Cohen and Levinthal (1990, p. 128) introduce the concept 'absorptive capacity', which refers to firms' ability 'to recognize the value of new information, assimilate it, and apply it to commercial ends.' The absorptive capacity concept has since been widely adopted in micro-level studies of knowledge flow, acquisition and exploitation in learning and innovation processes (Lau and Lo, 2015; Miguélez and Moreno, 2015). Giuliani (2005, p. 280) introduced the concept 'cluster absorptive capacity' (CAC), which she defines as 'the capacity of a cluster to absorb, diffuse and creatively exploit extra-cluster knowledge', which 'depends on the knowledge bases of its' firm members'. Giuliani's CAC concept places key emphasis on firms' absorptive capacity. Furthermore, 'the cluster absorbs external knowledge through "receptor" firms' that are referred to as technological gatekeepers' (ibid., p. 280).

Inspired by Laur et al.'s (2012) work on cluster initiatives as intermediaries, we suggest that other non-firm actors can be instrumental in the identification, assimilation and diffusion of external knowledge within clusters. As such, this paper offers a novel understanding of cluster dynamics (Trippl et al., 2015) and technology upgrading, by developing a refined CAC conceptualization. Additionally, the paper adds content to the absorptive capacity concept, which has been widely used (Trippl et al., 2017; Vang and Asheim, 2006), but insufficiently developed. To advance the understanding of intra-cluster and extra-cluster linkages in cluster dynamics, we investigate the role of cluster intermediaries (CIs), which are organizations that facilitate and promote knowledge flows between industry and knowledge institutions (Clarke and Ramirez, 2013). Thus, CIs couple extra-local knowledge linkages to cluster firms and enable localized knowledge spillover processes.

Through a qualitative study of two clusters that are comparable both in size and industry sector, but different in terms of their predominant knowledge bases, we develop typologies of intermediary roles with regards to CAC. The key aim of this paper is thus to enhance the understanding of the different roles of CIs in linking extra-cluster and intra-cluster knowledge, and how CIs contribute to CAC. The paper addresses the following research questions:

How and to what extent do cluster intermediaries facilitate extra-cluster linkages and provide new and vital knowledge among cluster firms?
What roles can cluster intermediaries take in various cluster contexts in order to enhance absorptive capacities?

Empirically, we analyse recent developments with regards to knowledge development and technological upgrading in two high-tech manufacturing clusters in two towns in Norway. Historically, both towns – Kongsberg and Raufoss – were hosts to key state military-related industry activities (weapons and ammunition respectively). Both were initially single-company localities specialized in defence industries, but gradually diversified into high-tech manufacturing clusters within automotive, aerospace and offshore subsea industries. Currently, some of the key cluster firms are upgrading their manufacturing processes by implementing advanced manufacturing technologies in their production facilities and/or upgrading their products by utilizing novel combinations of materials. By comparing the two clusters in Kongsberg and Raufoss with regards to recent strategies and capabilities for technological upgrading (including advanced technology platforms associated with I4.0), we discuss the significance of knowledge bases, knowledge linkages and the related role of intermediaries. The paper contributes to a refined understanding of CAC and the role of CIs in cluster development.

The paper proceeds as follows. In the next section, we discuss the cluster concepts with regards to I4.0, inter- and extra-cluster-linkages, firm- and cluster-level absorptive capacity, and the role of intermediaries. Thereafter, in Section 3, we present the qualitative research design and a brief narrative of the two empirical cases. In Section 4 we analyse and discuss the clusters' and CIs' current efforts in skills and technology upgrading, and propose a typology of CIs. Finally, in Section 5 we present our conclusions.

2 Cluster, technology upgrading and Industry 4.0

Research suggests that firms located in clusters tend to have better innovation performance than non-cluster firms (Audretsch and Feldman, 2004; Delgado et al., 2014). Cluster firms' enhanced performance is related to linkages between cluster firms, social capital, trust, a shared knowledge base and common pool of human capital, and the presence of supportive institutions (Ebbekink and Lagendijk, 2013; Kesidou and Snyjders, 2012).

Porter (2000) defined clusters as geographical concentrations of interconnected companies, specialized suppliers, and associated institutions in a particular field that compete but also cooperate. More recently, the conceptualization of clusters has become less stringent and more flexible with regards to relational qualities, but narrower with regards to the territorial dimension (Malmberg and Power, 2005). Chapman et al. (2004, p.382) understand cluster as 'concentrated groups of inter-linked firms and organizations occurring at the local and regional scales'. Cluster research has emphasized different dimensions of clusters: The interrelated firms could be in the same industry and have customers or suppliers in the same value chain (Porter, 2000), have non-market based interactions (Marshall, 1920; Bathelt et al., 2004) and benefit from a common labour pool (Marshall, 1920; Malmberg and Maskell, 2002). These different cluster qualities and intra-cluster relations are regarded as vital for cluster firms to share knowledge, innovate, and upgrade their technologies.

The knowledge bases that cluster firms draw on are supposed to influence the novelty of their innovations. Analytical knowledge embraces scientific and codified knowledge, and is often applied when creating new products or new processes (i.e. radical innovation). Synthetic knowledge concerns hands-on practical knowledge, which is typically applied to solve specific problems occurring in interactions with clients and suppliers. For firms relying on a synthetic knowledge base, the dominating form of innovation is thus considered incremental (Asheim and Coenen, 2005). Radical innovations may have disruptive effects for clustered firms (Molina-Morales et al., 2019).

Since the early 2010s, the manufacturing industry has been confronted with what some call a new digital revolution, referred to as Industry 4.0 (Schwab, 2016). I4.0 is used as a generic concept to embrace various technologies that may radically change both the nature and spatial patterns of manufacturing activities. Although no common definition of I4.0 exists, there is consensus that I4.0 covers a range of technologies such as autonomous robots, the Internet of Things (IoT), cyber-physical systems, additive manufacturing/3D printing, Big Data, artificial intelligence, and machine learning (Schwab, 2016; Götz and Jankowska, 2017). The disruptive potential is found in the combination of some or many of these technologies. In sum, I4.0 is predicted to change business models and have transformative effects on the organization of production, logistics and distributions, and the governance of value chains and networks. Many I4.0 technologies could reduce production costs (e.g. autonomous robots), which is essential for manufacturers in high-cost countries (Lund and Steen, 2019).

As a consequence of digital technologies' ability to ease interaction over longer distances, different value chain activities could become more geographically dispersed. As such, I4.0 may undermine some of the advantages of co-location provided by contemporary manufacturing clusters, as it reinforces the interconnection of firms across space, thereby creating international network associations (Alcácer and Cantwell, 2016). However, Götz and Jankowska (2017) argue that clusters are conducive to the development and implementation of new technologies (I4.0) because they ease interaction among multiple types of actors, including scholars and practitioners. Implementation of these new technologies requires a combination of synthetic knowledge and analytical knowledge. In manufacturing industries, skilled workers have a key role in workplace innovation. However, both skilled workers and the related vocational education system are challenged, as the actual discovery and introduction of these new technologies rely on analytical knowledge. In the face of emerging technologies, this emphasis on analytical knowledge must be reflected in educational programmes (Lund and Karlsen, 2019).

In clusters, the education system is typically well connected and adapted to the local industry (Lund and Karlsen, 2019) and mobility of skilled personnel provides knowledge spillover and territorially embedded knowledge bases (Malmberg and Maskell, 2002). Götz and Jankowska (2017) find location specific factors, such as an environment of collaboration and trust, favourable for the development of I4.0 technologies, particularly in early phase of testing and experimenting. However, Götz and Jankowska's (2017) emphasis on the internal qualities of clusters and cluster dynamics neglects recent attention to extra-cluster linkages and the need for extra-local knowledge to keep cluster firms innovative and competitive (Martin et al., 2018; Molina-Morales et al., 2019). Given that I4.0 is about combining different kinds of technologies and that specialized clusters rely on specialized competence and expertise, exploiting extra-local complementary knowledge sources seems inevitable in order for firms to achieve technological upgrading.

2.1 Intra-cluster and extra-cluster linkages

Bathelt et al. (2004) argue that the co-existence of key strategically developed extra-local knowledge linkages (referred to as global pipelines) and high levels of localized informal and formal knowledge sharing (referred to as local buzz), and their active coupling enable cluster firms' access to vital external knowledge while taking advantage of exclusive local knowledge. However, this line of argument has been criticized for reducing local interaction to informal social networks, and global linkages to strategically selected and formal networks, thus neglecting a wider spectrum of linkage forms (Grillitsch and Trippl, 2014; Trippl et al., 2015; Martin et al., 2018).

Knowledge exchange could take place on an international level through the value chain (customer-supplier relationships), mobility of skilled labour, formal collaboration between industry and R&D,

informal networks in virtual communities, participation in temporary clusters, and foreign direct investments/foreign ownership, and at a local level, through formal collaboration and mobility in the labour market (Trippl et al., 2017; Martin et al., 2018). However, the cluster debate tends to emphasize local/regional and international level linkages and often disregards the national level as a frame for industry-R&D linkages and policy implementation (Isaksen, 2009; Sæther et al., 2011). The latter point resonates with the original cluster approach by Porter (1990) and the literature on national innovation systems (Lundvall, 1992; Nelson, 1993, Fagerberg et al. 2009). A reasonable understanding is that regional, national, international, sectoral, and technological systems of innovation are overlapping (Sæther et al., 2011; Grillitsch and Trippl, 2014).

Agency has recently been suggested to have a vital role in innovation systems: Grillitsch and Sotarauta (2019) use the concept 'institutional entrepreneurship', whereas Hassink et al. (2019) introduce the related concept of 'system level agency'. The latter scholars point to actors who are capable of influencing the broader local industrial environment outside their own institutional/organizational borders. These actors could be research institutes that collaborate with regional firms in order to enhance their competitiveness or cluster organizations that work to promote either networking and joint development or market-related activities among cluster members (Hassink et al., 2019). In our cluster context, we refer to these actors as 'intermediaries', and as such we argue that they contribute to the absorptive capacity of clusters.

2.2 Firm-level absorptive capacity

In their seminal contribution, Cohen and Levinthal (1990, p. 128) defined absorptive capacity as the ability of firms to 'recognize the value of new, external information, assimilate it and apply it to commercial ends'. Furthermore, an organizations ability to see and evaluate new information (absorptive capacity) depends on the organization's prior related knowledge (Cohen and Levinthal, 1990). Firms' absorptive capacity has typically been a subject for quantitative research, in which proxy indicators have been investments in R&D, number of scientists, share of staff with higher education background (as measures of innovation input), and patents (as a measure of innovation output) (Crescenzi and Gagliardi, 2018) (see Volerda et al., 2010 for a review). These proxy indicators are easier to measure for large companies, in which the division of labour is high and respective accounting is more accurate than in SMEs, in which employees may have multiple functions and are thus harder to categorize.

These quantitative measurements are biased by indicators targeting analytical knowledge typically held by managers, researches and experts. However, synthetic knowledge embedded in shop floor practices is more challenging to capture in typical quantitative studies. By employing qualitative research methods when studying CAC, we could reveal in a better way the intra-organizational capacities of sharing knowledge and contribute a novel understanding of how intermediaries work with both local and extra-local firms and non-firm actors.

In sum, the firm's absorptive capacity relies on the expertise within the organization and the structure of communication within and between its subunits, as well as with the external environment (Cohen and Levinthal, 1990). This way of thinking also makes sense at an inter-organizational level, including a cluster level. As we move from the firm level to the cluster level of analysis, the conceptualization of absorptive capacity increases in complexity. This aggregation calls for further conceptualization of CAC.

2.3 Cluster absorptive capacity

Relatively recently, the absorptive capacity concept has appeared in studies of higher meso-levels of society such as regional innovation systems (Trippl et al., 2017), regions (Miguélez and Moreno, 2015), and clusters (Giuliani, 2005). Whereas some business management studies recognize that clusters have favourable conditions for absorbing external knowledge, they still have the individual firms and their absorptive capacities as the only unit of analysis (Lau and Lo, 2015, Crescenzi and Gagliardi, 2018; Zou et al., 2018). Other contributions connect absorptive capacities directly to the cluster (Giuliani, 2005) or to the region (Vang and Asheim, 2006), arguing that cluster/regional absorptive capacity is more than simply the sum of the absorptive capacities of all the firms in the cluster or within the region.

Giuliani (2005) explains what determines CAC by focusing on firms' knowledge bases, which are defined by Dosi (1988, p. 1126) as a 'set of information inputs, knowledge and capabilities that inventors draw on when looking for innovative solutions'. In her CAC taxonomy Giuliani (2005) distinguishes between 'basic' and 'advanced' stages of CAC, understood as ideal types representing a continuum. Basic CAC clusters are characterized by firms with weak knowledge bases, have weakly interconnected intra-cluster knowledge linkages, limited external openness, and an absence of firms that can act as technological gatekeepers. Firms in clusters with advanced CAC have very strong knowledge bases, contribute by investing in in-house R&D, have dense knowledge linkages, and absorb knowledge from extra-cluster sources with the help of technological gatekeepers. Moreover, Giuliani (2005) adds an 'intermediate' level of CAC that has medium scores on the factors mentioned above.

However, use of the levels of weak, intermediate and advanced CAC risks disregarding other combinations of advanced and weak knowledge bases and intra- and extra-cluster linkages, thus neglecting cluster heterogeneity. Clusters with weak knowledge bases could, for example, be compensated for by strong intra-cluster linkages and/or vital roles of gatekeepers, or vice versa. However, Giuliani (2005) stresses that clusters need technology gatekeeping, a process found in firms that have strong knowledge bases and making them capable of connecting extra-cluster knowledge and local knowledge systems (see also corresponding argument by Kesidou and Snyjders, 2012). We recognize that Giuliani does not make any distinctions between types of extra-cluster knowledge sources. In addition to her CAC taxonomy, we include the national innovation system as a level of significant extra-local knowledge linkages (Trippl et al., 2015; Chaminade et al., 2019). Furthermore, rather than adopting the term 'technology gatekeepers', which is primarily associated with economic actors, we opt for the term 'intermediaries', thus allowing for enhanced emphasis on the role of non-private intermediaries (Clark and Ramirez, 2013) in cluster development.

2.4 The role of intermediaries in cluster absorptive capacity

In addressing the role of agency in cluster dynamics and development, and given the firm focus in CAC studies to date, we include especially the role of local non-firm actors (Trippl et al., 2015; Bianchi and Labory, 2019). In our context, non-firm actors comprise knowledge and support institutions (including cluster organizations) that are vital for cluster development. Such institutions may work as intermediaries, creating arenas for knowledge exchange and building networks.

Intermediaries are regarded as brokers that 'connect and coordinate otherwise disconnected others' (Foster et al., 2015, p.436). In addition to this bridging work, intermediaries may also strengthen existing linkages. Intermediary organizations could have a vital role in building efficient regional technology-transfer systems between universities and firms, given that regional firms have sufficient absorptive capacities (Kodama, 2008). More specifically, they can coordinate projects, provide and diffuse knowledge, and help to adapt existing knowledge to new contexts (Clarke and Ramirez, 2013). Intermediaries are able to support the development of local assets such as workforce skills and competences through influencing, for example, regional and national policies on R&D and education (Smedlund, 2006). Through their influence on policy, intermediaries could be able to enhance the organizational support structure of the region (Trippl et al., 2017). Intermediaries will, to varying extents, be embedded in the clusters (Foster et al., 2015; Ter Wal et al., 2017). They should have field-specific competences and skills, as well as substantial knowledge about the region, which is important for their ability to recognize the needs of regional industry when facilitating interaction between production, development and research (Smedlund, 2006).

We understand CIs as organizations – both private and public – that promote overall CAC by linking clusters to extra-cluster knowledge sources, spurring technology transfer and organizing intra-cluster collaboration. In line with Clarke and Ramirez (2013, p.717), we define CIs as cluster organizations and brokers that facilitate knowledge flows between industry actors and knowledge institutions, and thereby contribute to processes of learning and capability building in cluster firms. As such, CAC depends on cluster firms' previous knowledge, but leans on the intermediaries' ability to access extra-local knowledge and translate knowledge for intra-cluster diffusion.

Researchers who conduct studies of clusters should be aware of place-specific contexts (Giuliani, 2005) in order to recommend context sensitive cluster policies (Asheim and Coenen, 2005; Tödtling and Trippl, 2005). In the same way the role of intermediaries should reflect on and be well adapted to the cluster context. In light of this, we generalize our empirical findings by developing CI typologies with regards to the provision of human capital and skills, and with regards to the facilitation of R&D and innovation collaboration. On the basis of a context-sensitive qualitative case study, we are able to pair these ideal CI types with ideal types of clusters.

3 Qualitative methods: comparison of two mature manufacturing clusters

In our comparative approach we study two mature clusters that are specialized in manufacturing industries and situated in semi-peripheral locations. Our research design is in line with a multiple case study approach (Yin, 2014) in the sense that the two clusters have both similarities and differences. The respective clusters in Raufoss and Kongsberg have some commonalities regarding industry sectors, but differ with regards to firm sizes, structure of networks, support institutions, and cluster specific knowledge bases. Both clusters are defined by shared competences among the cluster firms rather than the industrial sector to which the cluster firms belong. The Kongsberg cluster firms have overlapping competences in system engineering (SE – i.e. design, develop and implement advanced systems), which is a legacy from the former weapons factory. Competences and expertise in material technology and automation unite the manufacturing firms in the Raufoss cluster.

This study is based on data from 22 in-depth semi-structured interviews with representatives from cluster firms (9) and several local and regional institutions and organizations. The interviews were conducted during the period 2016–2019. The participants were predominantly managers from cluster firms, cluster organizations and knowledge institutions (R&D institutes, university and vocational education providers). Our primary interview data are supplemented by secondary sources (reports and journal articles on the studied clusters), observation, and participation at workshops organized by SFI Manufacturing[1]. By combining data from previous studies on these two clusters by other researchers, with our own empirical material, we rely on what Yin (2014) refers to as data triangulation, to enhance the reliability of our findings. Our interview data concerning the clusters' key characteristics are supported by findings in previous studies (Onsager et al., 2007; Isaksen, 2009; Johnstad and Utter, 2015). The data analysis relies on the coding of all of our sources of data which was done using the

[1] SFI Manufacturing is a partner in the Center for Research Based Innovation scheme (2015–2023) funded by the Research Council of Norway.

qualitative data analysis software NVivo, in which codes reflected theoretical concepts such as CI, CAC, and intra-cluster and extra-cluster linkages and knowledge bases.

3.1 Kongsberg case

Kongsberg is a medium-sized town by Norwegian standards, with 27,000 inhabitants, while the local labour market area compromises c.54,000 people (2019). The town of Kongsberg has its roots in a mining company, which was established in 1624 following the discovery of rich silver deposits in the mountains. Kongsberg has been identified as one of eight high-tech agglomerations in Norway.[2] and its development, along with other similar clusters in Norway, was dependent on the support of national political initiatives, public research institutions and public entrepreneurs (state-owned companies) (Onsager et al., 2007). Particularly during the 1960s and 1970s the state gave the core defence industry in Kongsberg a role in modernizing Norwegian industry. The agglomeration is thus a result of national industry and technology policies. Today, the Kongsberg high-tech agglomeration comprises c.20 companies and c.4000 employees, of this more than 70% employed in the five largest companies. Core activities are production of technological equipment and systems for the offshore, maritime, aircraft, automobile, and defence industries.

3.2 Raufoss case

The town of Raufoss has c.7500 inhabitants, whereas the local labour market area is currently home to c.70,000 people. The Raufoss cluster originates from Raufoss Ammunisjonsfabrikker (RA) (ammunitions factory), which was established in 1896. Similar to Kongsberg, Raufoss has played an important role in the development and modernization of Norwegian industry, and many of today’s privately owned companies located in Raufoss have their roots in divisions that evolved within RA (Johnstad and Utter, 2015). The Raufoss manufacturing cluster has 5 core companies and a network (TotAl-gruppen) of 46 small enterprises, which mainly serve the core cluster companies, and together the companies and small enterprises have c.5000 employees. Today the cluster consists of 17 consortia firm partners. Raufoss firms, which typically have mass production, emphasize incremental process innovation (Karlsen, 2019), whereas Kongsberg firms rather focus on product innovation.

4 Empirical analysis

In subsections 4.1-4.5 we first discuss how extra-cluster linkages influence firm-level absorptive capacities, and thereafter we elucidate the role of the cluster intermediaries and how they enhance CAC, before we discuss the findings.

[2] Onsager et al. (2007) define high-tech agglomerations as having minimum 1500 jobs and 50% or higher employment in high-tech industries in the local labour market area than the national average.

4.1 Firm-level absorptive capacity

Departing from the recognition of CAC as something more than the sum of firm-level absorptive capacities (Giuliani, 2005), yet dependent on cluster firms' existing knowledge base, it is necessary to elaborate the absorptive capacity of the individual firms in Kongsberg and Raufoss in order to understand their respective CAC. In subsection 4.1, we discuss the influence of education levels and both parent company and value chain linkages on the cluster firms' absorptive capacity.

4.1.1 Employees' educational level and overall R&D

The Kongsberg cluster is characterized by an analytical knowledge base, which is also reflected in the specialization of the cluster. Isaksen (2009) found that the proportion of employees in core cluster firms in Kongsberg with university degrees was c.70%, which implied that the average education level in Kongsberg was much higher than the national average (Onsager et al., 2007). These employees are mainly recruited from the Norwegian University of Science and Technology (NTNU) or the regional university (University of South-Eastern Norway). By contrast, the Raufoss cluster is characterized by a synthetic knowledge base. Approximately 25% of the employees in the Raufoss cluster firms have a university degree. The remaining employees are primarily technicians from vocational colleges, skilled workers from vocational secondary schools, or workers with experience- and industry-based trade certificates (Johnstad and Utter, 2015). According to our interviews, both Raufoss and Kongsberg cluster firms emphasize short distances between top management and workers on the shop floor as favourable for participatory innovation processes.

By tradition, the Kongsberg core firms have had a high share of R&D expenditures: half of the firms have spent more than 10% of their turnover on R&D activities. The R&D expenditures have been much lower for the core cluster firms in Raufoss, where only two firms have spent at least 10% of their turnover on R&D (Isaksen 2009). We believe the latter relates to lack of in-house R&D departments in Raufoss firms, which has historical explanations (see Section 4.2)

Following the line of argument in the literature on firm-level absorptive capacity (Crescenzi and Gagliardi, 2018), the above figures indicate that each Kongsberg cluster firm has a high absorptive capacity, whereas each Raufoss cluster firm has a low absorptive capacity.

4.1.2 Parent company and value chain linkages

In order to improve a firm's capacity to innovate, it is necessary to access external knowledge sources (Crescenzi and Gagliardi, 2018). Such sources can be found along the value chain and within the company structure of transnational corporations (TNCs). At least in principle, large firms can draw on more varied expertise within their organization, but may have difficulty in terms of coordination and socialization (Zou et al., 2018). Several of the Kongsberg and Raufoss cluster firms are subsidiaries or branch plants and find strength in being owned by a foreign parent company, as they benefit from competences and resources from the corporation's broader activities (Onsager et al., 2007). In Kongsberg, the head of research and technology at an aerospace manufacturer explained that they have a fruitful collaboration with their Swedish sister company, and that the parties draw on mutual advantages of considerable knowledge exchange (interview with head of R&D, 2017). In Raufoss, a company executive in an automotive branch plant, explained that they received help from their German parent company when implementing new robot technologies in production. The branch plant subsequently sent some of their employees to Germany for training and education (interview with company executive, 2016). The two examples illustrate how parent company linkages provide extra-local knowledge that improves the absorptive capacity of the cluster firms.

The cluster firms consider customers the most important source of knowledge for their innovations, particularly in the case of Kongsberg cluster firms, which deliver highly customized products in close interaction with their customers (Onsager et al., 2007). A component producer for an international defence industry takes part in customer organized workshops on topics such as robotization, digitalization and data capture (technical director, 2019). The core Kongsberg cluster firms draw on electronics firms and machining firms from the wider region of Eastern Norway and other suppliers dispersed around the country (Onsager et al., 2007) (interviews with business informants, 2016-17). In Raufoss, two local technology suppliers play key roles in implementing advanced manufacturing technologies in firms' production lines. A management executive at a defence and aerospace manufacturer claimed that it was 'a great advantage' to have the technology provider 'in the neighbourhood' (VP operations, 2018). Evidently, several external knowledge sources are important for the innovativeness of the cluster firms in Raufoss and Kongsberg. Given the respective dominant knowledge bases and supplier network structure, we may, as a point of departure, expect that individual cluster firms in Kongsberg are more directly exposed to cluster external knowledge impulses than are single cluster firms in Raufoss.

Whereas many quantitative studies base the CAC on proxies such as employees' educational level, R&D expenditure, and patents (Volerda et al., 2010; Crescenzi and Gagliardi, 2018), this qualitative study regards the function of cluster intermediaries (CIs) as essential in the development of CAC. Therefore, we explore the role of CIs in facilitating extra-cluster knowledge and their influence on CAC from the perspective of both the CIs and the cluster firms.

4.2 Cluster initiatives as cluster intermediaries

4.2.1 Historical linkages resulting in different CI function

The contrasting organization of the CIs in Raufoss and Kongsberg has historical reasons. The Kongsberg CI, (*Kongsberg innovasjon* – hereafter referred to as KI) ran the National Centre of

Expertise in Systems Engineering[3] (2006–2016). After the NCE funding ended in 2016, KI became an innovation company and incubator, and continues to take part in national innovation programs[4]. However, the Raufoss CI (SINTEF Manufacturing – hereafter referred to as SM) has historical linkages to the internal R&D unit that existed within the state-owned ammunitions company. SM found its existing form after a demerger in the 1990s, when the former in-house R&D unit became a separate (applied) R&D actor within the Raufoss industrial park. SM (partially owned by the Raufoss industry) thus came to function as a common good – R&D provider – for all of the cluster firms (Johnstad and Utter, 2015). By contrast, the core Kongsberg cluster firms have kept their R&D personnel in-house since the disintegration of the Kongsberg weapon factory in the late 1980s.

4.2.2 Private intermediary – enhancing firm absorptive capacity

The literature on intermediaries makes a distinction between non-private and private intermediaries (Clarke and Ramirez, 2013). SM in Raufoss has been the ‘public’ cluster organization that coordinated the collaboration between firms in the Raufoss cluster in the NCE Raufoss[5] period (2006–2016), focusing on automation and light-weight materials which form a cluster specific knowledge base. During the same period, under different names, it was a privately owned R&D institution. In practice, it is hard to separate the NCE cluster initiative from the private R&D institute. According to a senior advisor at SM, this is intentional, and the idea is that they are supposed to go ‘hand in glove’, where ‘NCE is the glove and SM is the hand’ (interview with senior advisor, 2017). Thus, SM is a public-private intermediary, serving cluster firms in different ways. SM continues to take part in national innovation programmes.[6]

As a private R&D institute, SM provides the core cluster firms with access to laboratory facilities and experts/researchers on materials and automated production processes. Today, SM functions as the cluster firms’ laboratory, which according to an R&D manager at an automotive cluster firm was of key importance when they showed international customers and partners their ‘R&D tool kit’ (interview with R&D manager, 2017). As a private intermediary and R&D provider, SM contributes to enhance firms’ absorptive capacity. SM also has an important function for extra-cluster firms. An aerospace manufacturer in the Kongsberg cluster explained that SM ‘is an important knowledge and

[3] In 2006 a National Centre of Expertise (NCE) on Systems Engineering was established with financial support from the national support organizations Innovation Norway, the Research Council of Norway, and the Industrial Development Corporation of Norway (Siva).
[4] The cluster in Kongsberg (NCE System Engineering) has recently been integrated into the various national groupings such as DIGITALNORWAY – Toppindustrisenteret, NCE iKuben, and NCE Smart Energy Markets. Omstillingsmotor is a grouping of established clusters in Kongsberg, Raufoss and Halden that should accelerate process of digitalization and enhance the innovation capability in more than 200 SMEs in Norway.
[5] National Centre of Expertise on lightweight materials and automated production
[6] Initiated and controlled by SM, Raufoss currently hosts the Norwegian Manufacturing Technology Center (NMTC) as part of the Catapult Centre programme funded by the Norwegian Ministry of Trade, Industry and Fisheries.

technology provider' (management executive, 2017) for the company, which collaborates more with SM and other Raufoss firms, than with firms within the Kongsberg cluster.

In addition to SM, there is a second intermediary in Raufoss, the TotAl-gruppen (Total group, TG), which is geared towards suppliers (small enterprises) located outside the industrial park. TG's primary function is to develop collaboration and joint action within a business network of 46 small enterprises. TG was established in 1998 – initially with 15 firms, many of them spin-offs from RA – in order to ensure stability for the suppliers in terms of access to customers. The manager of TG underlined that craft skills, including tacit knowledge, was essential for member firms' performance. However, some of the larger firms in the cluster are also members of the group, and thus contribute to the development of both the network and the suppliers. There is certainly a duality to this, as the collaboration also enables core cluster firms to, in some degree, take control of the development in their own supply chain, 'ensuring that all these suppliers are qualified to deliver to us [core cluster firms]' (representative at SM, 2017). This type of collaboration could have been more difficult if TG had not existed. We thus recognize TG as a subordinate intermediary that is connected to the main Raufoss CI, reflecting how territorially embedded the local manufacturing firms are.

Whereas SM has mainly facilitated network collaboration, particularly with regards to R&D, the efforts of KI have mainly been to enhance firms' absorptive capacity by providing the cluster firms with skilled candidates.

4.2.3 Enhancing firms' absorptive capacity through education and training

Systems engineering has its origin in American defence and since the 1960s it has been developed as a cluster specific knowledge base for the Kongsberg industry. This interdisciplinary field is about developing advanced systems and complex products for several industries. This legacy from the former weapons factory was highlighted in the cluster initiative's application for NCE Systems Engineering and has successively been a focal area for both higher education and research in Kongsberg. The most prevalent example of this is the development of a master's programme in systems engineering at the regional university in 2006, in close collaboration with core cluster firms, and the subsequent establishment of the Norwegian Institute for Systems Engineering at USN in 2012. The content is very much adapted to the needs of the cluster firms, which host the candidates during internships and often recruit candidates before they complete their degree (NCE SE 2016).

Supported by KI, USN operates alongside other providers of skilled candidates, on lower levels. Kongsberg Technology Training Centre (K-Tech) provides industry-relevant vocational education and apprenticeships. Three major companies established K-tech in 2008 to meet their need for skilled workers. Their workforce becomes technologically upgraded as the students are given access to up-to-date machinery and are provided with a training arena similar to that on 'real' production lines. The vocational college in Kongsberg has developed a new educational programme that covers topics such as the Internet of Things, industrial intelligence, autonomous systems, and Big Data, which are technologies that are expected to permeate future industry (Lund and Karlsen, 2019).

In sum, we recognize that the CI and supportive institutions in Kongsberg have contributed substantially to the renewal of educational programmes and training, and prepare cluster firms' knowledge base for the implementation of new technology. They are very much directed towards providing the industry with industry-relevant candidates in engineering and other skilled workforces with up-to-date qualifications. Provision of highly skilled candidates with skills in vital technologies is important for the absorptive capacities of core cluster firms. They demonstrate high ambitions with regard to the implementation of I4.0 technologies (interviews with business representatives from three key cluster firms, 2017-19). The lack of a united intermediary for coordinating providers of industry-relevant education and training at different levels of education reflect the more institutionally fragmented character of the cluster in Kongsberg compared with the more unified cluster and CI in Raufoss. However, in Raufoss the CI has been less successful in developing collaborations with regional and local education institutions, notwithstanding recent efforts at the vocational college (Lund and Karlsen, 2019).

4.3 Cluster intermediaries – facilitating extra-cluster knowledge linkages

4.3.1 *SM – accessing actors in the national innovation system*

By virtue of being a public intermediary SM has facilitated two Centres for Research-based Innovation (SFI), SFI Norman (2007–2014) and SFI Manufacturing (2015–2023) aimed at improving manufacturers' competitive advantage by implementing advanced manufacturing technologies and material technology in production. Four core cluster firms in Raufoss and one in Kongsberg participate in SFI Manufacturing and additional eight extra cluster firms participate in the centre coordinated by SM. In the ongoing SFI Manufacturing, key knowledge providers are NTNU (Trondheim) and SINTEF (Trondheim and Oslo). Thus, SM has a key role in accessing extra-cluster knowledge and technology on a national level. In line with Clarke and Ramirez' (2013) discussion on the role of CIs, SM also has a key role in business network formation. Some of the cluster firms' representatives reported that their participation in the ongoing SFI had enabled them to build relationships with firms located outside the cluster, which they could benefit from in future projects and collaborations (own interviews).

Within the SFI Manufacturing framework, SM has put I4.0 on the agenda. The interdisciplinary centre focuses on robust and flexible automatization, multimaterial products and production processes, and sustainable and innovative organizations. The projects include industrial robots as well as flexible and integrated production systems employing enabling digital technologies, and large-scale robotized additive manufacturing. Within this framework SM has organized related R&D projects, with various funding. Furthermore, on the initiative of SM, the state awarded Raufoss a Norwegian Catapult Centre in manufacturing technology. The centre will consist of six mini-factories equipped with I4.0 technologies and will work as an important learning arena for SMEs, larger companies, R&D, and educational institutions.

As Industry 4.0 is a fuzzy concept, it is no surprise that cluster firms have different and vague understandings of what I4.0 is about. For the firms, the common denominator is that it I4.0 refers to new technologies that may have disruptive effects. Key firms already have extensive application of autonomous robots and automated production lines, and two of them are quite advanced in these regards. As efforts initiated by SM are partly about implementation of more technologies (or more advanced versions) than they already have, the implementations at most appear as incremental innovations. A more limited number of core companies see the potential in additive manufacturing (3D-technologies), and few have taken initiatives and even fewer have implemented such technologies. Some of the business actors mentioned that I4.0 was about connecting different parts of the production process and even the supply chain, but technological integration of cyber-physical systems has not yet been realized.

Although SM provides access to new knowledge, new technology and extra-local firms that potentially could be collaboration partners, and as such enhances potential CACs (on acquisition and assimilation of knowledge), these efforts do not automatically lead to realized cluster absorptive capacities (on transformation and exploitation of knowledge), to use the conceptualization of Molina-Morales et al. (2019). Firms' representatives highlighted the difficulties with constantly trying to keep up with what was happening in terms of new technology and related knowledge, when their time was 'eaten up by their working day and specific customer projects' and day-to-day goals in terms of production (head of development at a car component manufacturer, 2016 – authors' translation). According to the head of development, although SM could help to facilitate research project application and participation, it was difficult for firms in extremely competitive industries (e.g. automotive) to make long-term plans for technology implementation. In sum, as a CI, SM has pushed cluster firms' attention towards I4.0 and taken corresponding initiatives in R&D projects, but the actual (and potential) implementation of these new technologies lies ahead. We could thus conclude that SM has supported potential CAC, and that realized CAC is a matter of the future.

4.3.2 NCE SE/KI – linkages to primarily international universities

Isaksen (2009) argues that in Kongsberg core firms' strategic knowledge providers have been national (NTNU, SINTEF, Norwegian Defence Research Establishment) or international universities. A representative one of the core cluster firms in Kongsberg mentioned that they collaborated with NTNU on some projects (technical director of a defence and aerospace manufacturer, 2019), but that the collaboration mainly revolved around student recruitment. However, since the late 2000s, local knowledge institutions seem to have gained positions as providers of human capital, expertise and skills.

Through its engagement in developing the master programmes in systems engineering and establishing the Norwegian Institute for Systems Engineering (NISE), the Kongsberg CI has been instrumental in establishing relations with national and international universities. One of the key institutions in this regard is the Stevens Institute of Technology in the USA, which has been an important source of extra-regional knowledge for USN in terms of providing professors for teaching. According to an NCE SE representative, the relationship with Stevens was essential in order to provide master's courses. Simultaneously, the Stevens Institute of Technology, which was familiar with two of the largest firms in the cluster 'regarded Kongsberg as an interesting laboratory' with a diverse industry base (NCE SE representative 2017). Today, NISE also collaborates with Georgia Tech (USA) on model-based systems engineering, Stanford University (USA) on design and NTNU on 'lean product development' (representative of NCE SE, 2017).

In addition to developing education programmes, NCE SE initiated a three-year research programme that coupled the four cluster firms to USN and NTNU in Trondheim. The 'Knowledge-based Development' project aimed to improve the firms' efficiency in product development and resource utilization, and entailed identifying, sharing and exploiting best practices from the cluster firms' different industry sectors (NCE SE, 2016).

Despite having initiated some research activity, the lion's share of NCE SE's activities as a CI has revolved around providing cluster firms with master's candidates in SE and sourcing industry-relevant knowledge from national and international universities.

4.4 Summing up CIs and cluster external linkages

In, sum, we find that cluster firms in Kongsberg mainly rely on absorptive capacities at the firm level, whereas cluster firms in Raufoss to a high degree rely on CAC. The findings reflect how Raufoss and Kongsberg differ substantially. First, cluster firms in Raufoss typically utilize local suppliers, whereas key firms in Kongsberg mainly use extra-local suppliers. Second, and related to the respective network structures, the two clusters differ in their predominant knowledge base (analytical in Kongsberg versus synthetic in Raufoss). In line with Isaksen (2009), we recognize that cluster firms have varied access to distant and proximate knowledge sources, dependent on the dominant type of knowledge bases. Cluster firms dominated by analytical knowledge bases are able to source knowledge nationally and internationally, whereas cluster firms characterized by synthetic knowledge bases rather source knowledge locally and regionally. Potentially, due to their employees' short cognitive distance to academics at R&D institutions, the Kongsberg cluster firms seem to have higher firm-level absorptive capacities in terms of inhouse R&D resources compared with the Raufoss cluster firms.

The clusters' contrasting structures are legacies from different outcomes of restructuring processes, in which Kongsberg cluster firms retained their internal R&D units, while Raufoss established SM as a common cluster R&D unit. However, they are also a result of the different knowledge bases that frame the respective cluster intermediaries' support for accessing vital extra-cluster knowledge sources.

Based on the clusters' contrasting legacies and knowledge bases, the CIs have taken on different roles. In Raufoss the local R&D institute works as both a public and a private intermediary (Clarke and Ramirez, 2013). As a private intermediary, SM engages with cluster firms in applied R&D projects, and as such it maintains local networks. As a public intermediary (e.g. in matters of public funding), SM couples to a wider, predominantly national innovation system. In Kongsberg the intermediaries focus on the educational systems and as such they provide core cluster companies with relevant candidates. Both university and key firm linkages are able to maintain international linkages and exploit foreign knowledge sources. Clusters characterized by synthetic knowledge bases should therefore be a target for CIs' support for accessing vital extra-cluster knowledge sources.

4.5 Discussing a typology of cluster intermediaries

In light of our empirical findings, we suggest two ideal types of CIs, each of which reflects and is well adjusted to the firm structure and sociocultural qualities of the respective cluster. First, we suggest two main types of CI functions/roles: (1) the human capital and skills providers that mainly work through the local labour market, and (2) the R&D and innovation collaboration facilitators that mainly work through networks of firms and non-firms (Table 1). The former (human capital and skills providers) are typically found in clusters consisting of firms that rely more on firm-level absorptive capacities and in which firm collaboration takes place more at arm's length. By contrast, R&D collaboration facilitators are typically found in clusters consisting of locally networked firms, where they are deeply involved in trust-based collaboration and where cluster firms rely more on cluster-level absorptive capacities.

Table 1. Typologies of clusters and intermediaries with regard to absorptive capacities

Cluster type

Cluster intermediary

	Extra-cluster networked firms drawing on analytical knowledge base	Intra-cluster networked firms drawing on synthetic knowledge base

Human capital and skills providers	**A**	B
R&D and innovation facilitators	c	**D**

Source: Authors' own table

A – This combination is typical. Given the high firm-level absorptive capacities in terms of R&D units staffed with highly educated employees, firms have a high demand for human capital provision and skills support in order to maintain and develop their firm-level absorptive capacity further.
b **–** This combination is less typical. Due to their limited division of labour and dominance of synthetic knowledge bases, cluster firms have a low share of employees with high educational levels. Cluster firms' demand for skills support and existing educational programmes is directed towards acquiring synthetic knowledge basically from training on the shop floor. In the face of new technologies, the cluster firms may have shortages of analytical knowledge bases on which to draw.
c **–** This combination is less typical. Cluster firms are less in need of local R&D and innovation facilitators due to their reliance on their own analytical knowledge bases and high firm-level absorptive capacities. Insofar as they are affiliated to TNCs or integrated into global production networks, they are able to exploit extra-cluster R&D networks on their own.
D – This combination is typical. R&D and innovation facilitators compensates for shortages in firm-level absorptive capacities. The CIs fit well with the trust-based network structure and territorially based firms typical for such clusters. As far as cluster firms regard the CI as a common good, the CIs are well adapted to the industrial and institutional context of the cluster, in which they may enhance CAC.

A and **D** appear as typical combinations of cluster intermediaries and cluster contexts. However, in real cluster contexts hybrid combinations may appear. Cluster policy should consider including both types of CIs. Based on our findings, we recommend that clusters firms (appearing in the **D** combination) should develop their absorptive capacities in form of high-tech expertise and skills in order to participate in and exploit R&D projects, not at least in the face of I4.0 technologies. This may depend on CIs' ability to provide industry-relevant and skilled candidates (including the frame of the b combination). In practice, this means that policymakers and cluster intermediaries should learn from other cluster experiences when adapting their own models. External impulses are particularly timely in the face of new (disruptive) technologies.

However, from our study of cluster firms, we recognize some limitations in knowledge acquisition and particularly in the exploitation of the new technologies. In line with the conceptualization of Molina-Morales et al. (2019), most of the cluster firms in Kongsberg and Raufoss have built up potential capability, partly with help of CI initiatives. Several cluster firms have already realized their capabilities by implementing less advanced I4.0 technologies, such as industrial robots. More advanced I4.0-technologies, such as 3D-printing, are only exceptionally realized and then in a very limited number of firms. We agree with Götz and Jankowska (2017) that clusters may work as a favourable environment for absorbing I4.0 technologies, but with some conditions. For cluster firms, territorial embeddedness and trust-based relations and collaboration do not suffice in terms of absorbing these new technologies. Further cultivation and exploitation of extra-cluster linkages is essential. In case such linkages are limited, cluster intermediaries could create, stimulate and develop them.

5 Conclusions

As the roles of clusters and cluster initiatives continue to be of interest to both researchers and policymakers, this paper provides novel insights into how cluster organizations take on different roles as intermediaries, depending on institutional and contextual preconditions. The paper adds to the ongoing debate on cluster dynamics by proposing a novel conceptual framework, combining the intermediary and absorptive capacity concepts, for investigating the role of non-firm actors in different types of clusters. Furthermore, the paper suggests that the proposed conceptual framework is productive for investigating different types of manufacturing clusters and can form a basis for suggesting cluster policy measures.

In line with Giuliani, the paper recognizes CAC as a quality beyond the sum of firm-level absorptive capacities. We find that CIs and their knowledge linkages are essential to enhance CAC. Our paper makes a contribution beyond Giuliani's CAC typology, as our approach is more sensitive to various combinations of qualities related to absorptive capacities. One the one hand, we recognize that clusters with predominantly analytical knowledge bases on the firm level are in less need for cluster intermediaries. On the other hand, clusters with limited analytical knowledge could benefit from being compensated by the help of vital CIs.

We recognize that intermediaries rely on knowledge institutions and firms on multiple scales in their efforts to renew cluster firms. Whereas Giuliani (2005) does not make any distinctions on the scale of extra-cluster knowledge linkages, we find national innovation systems particularly significant for technology upgrading among cluster firms. This is probably typical in the context of a coordinated market economy such as Norway. With regard to varieties of capitalism, we would expect that there is fertile ground for CSs in coordinated market economies (CMEs) compared with liberal market economies (LMEs). CMEs tend to have institutional capacities for collaboration across firms, R&D institutions and educational providers that are well supported by state funding. Almost by definition, CMEs have sociocultural conditions for trust-based collaboration between firms and between firm actors and non-firm actors. Related to these CME characteristics, the Norwegian industry consists mainly of SMEs in which there are short distances between top management and workers on the shop floor – traits that are reflected in the two cases presented in this paper. Our findings may thus have limited relevance for economies consisting mainly of larger firms.

Concerning policy recommendations, cluster policy should carefully consider how cluster organizations could contribute to cluster development by taking on various roles as intermediaries. Such intermediaries should be sensitive to existing local contexts and, more importantly, they should be able to accommodate future needs for renewal. Policymakers at the national level could draw on local and regional institutions' and policymakers' key experience with and knowledge about regional industry in order to develop national cluster policies that better accommodate the diverse needs of the industry. Furthermore, arenas for knowledge exchange across clusters and between cluster intermediaries could be developed in order to stimulate discussion, learning and sharing of experiences.

In light of this study, the Norwegian context and more general literature on varieties of capitalism, we would expect that cluster intermediaries could operate under more favourable institutional conditions in CMEs compared with LMEs. The direction for future research should be to conduct international comparative studies on how cluster intermediaries interact with multiple scales of support institutions. This should include comparisons across varieties of capitalisms and across the dimension of firm-size structures.

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Department of Geography and Regional Research
University of Vienna

Contact person: Michaela Trippl
Universitätsstraße 7/5/A0528, 1010 Vienna, Austria
Tel.: +43-1-4277-48720
E-Mail: Michaela.trippl@univie.ac.at
https://humangeo.univie.ac.at/

Department of Socioeconomics
Vienna University of Economics and Business

Contact person: Jürgen Essletzbichler
Welthandelsplatz 1, 1020 Vienna, Austria
Tel.: +43-1-31336/4206
E-Mail: juergen.essletzbichler@wu.ac.at
http://www.wu.ac.at/en/department-socioeconomics

Institute for Urban and Regional Research
Austrian Academy of Sciences

Contact person: Robert Musil
Postgasse 7/4/2, 1010 Vienna, Austria
Tel.: +43-1-51581-3520
E-Mail: robert.musil@oeaw.ac.at
https://www.oeaw.ac.at/en/isr/home/

Department of Working Life and Innovation
University of Agder

Contact person: Arne Isaksen
Jon Lilletunsvei 3/A161, Grimstad, Norway
Tel.: +47-37-23-33-53
E-Mail: arne.isaksen@uia.no
https://www.uia.no/en/about-uia/faculties/school-of-business-and-law/department-of-working-life-and-innovation

Department of Geography
Kiel University

Contact person: Robert Hassink
Hermann-Rodewald-Str. 9, 24098 Kiel, Germany
Tel.: +49-431-880-2951
E-Mail: hassink@geographie.uni-kiel.de
https://www.wigeo.uni-kiel.de/en/