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Overcoming barriers to new regional industrial path development: The role of a centre for research-based innovation

Nina Kyllingstad

Department of Working Life and Innovation, University of Agder, Grimstad, Norway

Correspondence
Nina Kyllingstad, Department of Working Life and Innovation, University of Agder, Jon Lilletunsvei 9, 4879 Grimstad, Norway.
Email: nina.kyllingstad@uia.no

Abstract

How regional industries can develop in an economically sustainable way is high on the research agenda. While the literature on regional change has focused primarily on historical case studies, it has said less about the barriers that hinder the desired change. This article contributes to a better understanding of barriers in regional innovation systems that hamper new regional industrial path development. Furthermore, the article analyses how a new knowledge organisation, the Centre for Research-based Innovation Offshore Mechatronics in the Agder region of Norway, can contribute to overcoming these barriers. The Centre, which is a policy instrument funded by the Research Council of Norway, aims to contribute to path extension and potentially path modernisation. However, since its foundation, oil prices have dropped severely, resulting in new conditions for the Centre and its partners. The article concludes by discussing whether and how the Centre has contributed to overcoming the barriers that hinder developments beyond path extension.

1 | INTRODUCTION

All regions have a constant need for industrial renewal, which becomes more evident in times of increased globalisation and digitalisation (Frangenheim et al., 2020). Evolutionary economic geography is a strand of literature occupied with explaining the development of new regional industrial paths. However, in recent years, shortcomings in the established literature have been observed due to their neglect of multi-actor approaches, multi-scalar perspectives, the integration of expectations and vision, and intra-path relations (Hassink et al., 2019). Other scholars have focused on key conditions and reinforcing mechanisms for path development, as well as the barriers preventing the materialisation of these conditions (Steen & Hansen, 2018). These shortcomings represent a multitude of additional factors that might explain the lack of development of new industrial paths. Although not encompassing all perspectives, much of the recent literature can be structured into aspects of the regional innovation system (RIS) relating to actors, networks, and institutions. By implication, when discussing what might contribute to new industrial path development, the discussion should also consider how actors, networks, and institutions can act as barriers, which has received less attention in the literature. This article, therefore, poses the theoretical research question: what are the barriers in different parts of the regional innovation system for new regional industrial path development? And what are potential ways of lowering or overcoming these barriers?

Barriers are often discussed in terms of factors that have been acknowledged in retrospect as hindering innovation. It is impossible to say in advance whether innovations would have occurred in specific situations had there been no barriers. However, based on the literature, barriers facing new industrial path development in the RIS have been identified, along with potential strategies to overcome them (Grabher, 1993), and this article focuses on how a new knowledge organisation in a RIS may contribute to overcoming barriers for new path development.

The empirical case on which this article is based is the new knowledge organisation—the Centre for Research-based Innovation Offshore Mechatronics (SFI OM)—which is a policy instrument funded by the Research Council of Norway (RCN). The SFI OM is tied to the oil and gas industry in the Agder region of southern Norway, which can be categorised as a specialised RIS with a long history of subcontracting to the oil and gas industry. When the partners applied to establish the SFI, the oil and gas industry was at its peak. However, after the application was granted, oil prices dropped, leading to substantial layoffs and decreasing turnover in oil-related firms in Agder. These conditions offered an opportunity to study how the changing external conditions affected an SFI heavily involved in the oil and gas industry. The promotion of an already strong industry through policy initiatives is in line with arguments in favour of building on regions' unique capacities. However, scholars have started to recommend that strategies that only maintain existing specialisations in a region are insufficient for ensuring long-term competitiveness (Asheim et al., 2011; Isaksen et al., 2019).

With the SFI's initial aim of further strengthening the already strong oil and gas industry in the region, the most likely outcome of its activities would be *path extension*, with incremental innovation only leading to a continuation of the already existing industrial path (Isaksen et al., 2018), or, in a best-case scenario *path modernisation,* involving industrial renewal through major changes based on new technologies or organisational innovations (Isaksen, Tödtling, et al., 2018). The literature on new industrial path development acknowledges that development is not only a result of exogenous shocks, but also rather based on various regional factors, including resources and competencies (Martin, 2010). In this context, the SFI OM case serves as a good example for studying the extent to which, and in what ways, a new knowledge organisation can contribute to overcoming barriers inhibiting new regional industrial path development. The argument is that the downturn in the oil and gas industry might have altered the SFIs original focus on strengthening the existing, leading

industry in the region and promoted more diversified thinking. The empirical research question is, therefore: what are the barriers in the organisationally thick and specialised region of Agder facing new regional industrial path development, and how has the SFI OM contributed to overcoming these barriers?

The next section introduces the theoretical framework which provides a foundation for the analytical framework. Then, the context and methods of the study are discussed before continuing with the empirical findings. The final section of the article presents its conclusions including a discussion on the implications of the study and prospects for future research.

2 | THEORETICAL FRAMEWORK

2.1 | Regional innovation systems

The oil and gas industry and the SFI OM operate in a regional context and are thus part of a RIS. A RIS consists of three main components: actors, networks, and institutions (Asheim et al., 2019). The RIS literature argues that innovation does not occur in isolation but is dependent on interactive learning that takes place between actors in subsystems (Asheim et al., 2019).

As shown by Isaksen and Trippl's (2016) typology, not all RISs are alike. They distinguish between organisationally thick and diversified RIS, organisationally thick and specialised RIS, and thin RIS. The first category can be identified by its relatively large number of different industries and its multiple R&D institutions and support organisations. The second type is marked by its specialised industry structure, accompanied by a narrow support structure. The third RIS shows less developed forms of both R&D and industry structure. The Agder region is characterised as organisationally thick and specialised, due to its dependence on the oil and gas industry and the robust support structure promoting this industry, which contains an industry cluster, an SFI and a Mechatronics Innovation Lab (MIL). The increased specialisation of the region is evident in a report by Herstad and Sandven (2017) which explored how Norwegian RIS configurations evolved from 2004 to 2012. Regarding the Agder region, they highlighted that:

> Innovation activity in general and local research system collaboration, in particular, has become more specialised, that is, more dominated by a limited number of industries that presumably are strongly dependent on growth impulses from the Oil & Gas industry. (Herstad & Sandven, 2017, p. 49)

Thus, the Agder region is in danger of becoming over-specialised and their advice is to strengthen the RIS by broadening the technology and sector scope (Herstad & Sandven, 2017).

2.2 | Path development

The concept of RIS has often been criticised for being too static. However, the path development literature has contributed to understanding dynamism and change within a RIS. The concept of path development is a key concept in evolutionary economic geography, which sees future industrial development as dependent on history (Martin & Sunley, 2006). Further, insights into how new regional industrial paths emerge are explored in works discussing paths as a process (Martin, 2010; Martin & Sunley, 2006), in works on related and unrelated variety (Boschma & Frenken, 2011;

Fagerberg, 2005; Frenken et al., 2007), as well as in some of the literature on RIS (Asheim & Gertler, 2005; Isaksen, 2014).

As with the explanatory factors behind new regional industrial path development, the terminology used to describe different paths also vary. This article follows a strand of literature that uses new path development as a general term covering different typologies of regional industrial paths and their distinguishing mechanisms (Isaksen et al., 2018; Isaksen & Trippl, 2016). As noted, this article focuses on an organisationally thick and specialised region. Because this type of region is lacking "internal diversity of industries, knowledge bases, supporting organisations and institutional forms that are seen as critically important for developing new regional industrial paths" (Asheim et al., 2019), they most often promote path extension, which is described as "business as usual" or path modernisation, which involves renewal of the existing path based on new technologies or organisational innovations. The article focuses on how a new knowledge organisation in a thick and specialised RIS might contribute to moving beyond path extension and modernisation.

2.3 | Barriers in an organisationally thick and specialised RIS

Stable RISs, such as the specialised RIS in the Agder region, are more likely to be geared towards incremental innovation and to be less adaptable to radical innovation (Boschma et al., 2017). The barriers to industrial renewal have been discussed from different perspectives for many years; for example, in the literature on lock-in and system failures (Grabher, 1993), innovation system failures (Chaminade et al., 2009; Woolthuis et al. 2005), and transformation failure (Grillitsch & Trippl, 2018; Weber & Rohracher, 2012). The barriers associated with these concepts have usually been identified as issues in the system itself, with less attention paid to individual actors. However, recent literature has defined actors who can contribute to changing a RIS in terms of firm-level entrepreneurs and agency, and system-level entrepreneurs and agency (Isaksen et al., 2019; Isaksen, Kyllingstad, et al., 2018; Kyllingstad & Rypestøl, 2018). Firm-level agency relates to how actors start new organisations or initiate new activities in existing ones; in either case, these innovations might lead to changes in the RIS and possibly new growth paths (Isaksen et al., 2019; Isaksen, Kyllingstad et al., 2018; Kyllingstad & Rypestøl, 2018). System-level agency, on the contrary, "is based on actions or interventions able to transform regional innovation systems to better support growing industries and economic restructuring" (Isaksen et al., 2019, p. 5). Although the barriers relate to knowledge at the level of the firm, both firm- and system-level agency can contribute to overcoming them (Isaksen et al., 2019). Miörner and Trippl (2017) also present a typology of how actors can change environments from constraining to enabling ones. Although this typology is significant, this article discuss barriers in accordance with the elements of a RIS (actors, networks, and institutions), in line with the article by Grillitsch and Trippl (2018), which discusses barriers to restructuring for actors, networks, and institutions in the RIS.

2.3.1 | Actors

Regarding the actor-level barriers, actors may lack the resources, knowledge, or competencies required to create new knowledge (Chaminade et al., 2009; Woolthuis et al., 2005). In thick and specialised RISs, the actors' knowledge tends to be highly specialised, which might pose challenges when adaptation to new technologies becomes essential. Even though knowledge might be created within the RIS, Asheim et al. (2019) argue that for thick and specialised RISs, existing knowledge

is not enough to move the system beyond path extension or modernisation. These RISs have deep knowledge that is limited to a few domains, thus, creating a need for nonlocal linkages to inject new or complementary knowledge (Trippl et al., 2018). The success of this injection depends on the absorptive capacity of the RIS (Cohen & Levinthal, 1990), which may be weak in a thick and specialised RIS (Trippl et al., 2018).

Concerning collaboration and knowledge exchange between research environments and industries in a specialised RIS, different knowledge bases might have an impact. Researchers are often characterised by an analytical knowledge base, where scientific knowledge is considered important and is the driver for innovations, while the industry is often characterised by a synthetic knowledge base, characterised by its experienced-based knowledge in innovation processes (Asheim & Gertler, 2005). In firms dominated by a synthetic knowledge base, innovations are less disruptive, making spinoffs, and the formation of new firms less frequent compared to firms with an analytical knowledge base (Asheim & Gertler, 2005). The different knowledge bases are also connected to different innovation modes, where different knowledge means that innovation is facilitated in different ways. While researchers are often familiar with the science, technology, and innovation (STI) mode of innovation, the industry is usually familiar with the doing, using, and interacting (DUI) innovation mode. The first of these generally relies more on explicit and global knowledge, while the latter usually relies on implicit and local knowledge (Jensen et al., 2007).

The different knowledge bases and innovation modes might also influence the absorptive capacity of partners working together in an SFI. Generally, there is an understanding that a firm's innovation capability is stimulated by science and that collaboration and knowledge exchange between industry and scientific partners will enhance innovation (Ankrah & Omar, 2015). How policy may facilitate this collaboration or interaction has long been discussed in the literature (Kaufmann & Tödtling, 2001). The SFI has the potential to be such a facilitator, if it manages to bridge the two spheres by making the operational principles of each sphere compatible and simultaneously maintaining flexible interaction between different innovation partners to avoid lock-ins of established trajectories (Kaufmann & Tödtling, 2001).

Given the barriers mentioned above, there is a potential for a new or altered knowledge organisation to overcome these barriers by introducing new knowledge into the RIS, either by developing it internally, combining it with knowledge held by already existing actors, or introducing nonlocal linkages and novelty from the outside, thus, acting as a firm-level entrepreneur. The potential for new regional industrial path development may also be higher if the new knowledge organisation can offer support for the restructuring of the regional economy, consequently acting as a system-level entrepreneur.

2.3.2 | Networks

In a RIS, several networks connect the different organisations. The characteristics of these networks—such as too much or too little interaction—can create interaction failures (Woolthuis et al., 2005). In an organisationally thick and specialised RIS, the industrial base is narrow, and knowledge and support organisations are tailored to this base (Asheim et al., 2019). Such an environment creates strong interdependencies and connectedness, which signal the potential for a strong network failure when the infusion of new knowledge from outside the network is limited. This low capacity to receive new and relevant knowledge is also referred to as functional lock-in (Grabher, 1993). In addition, the capacity to *attract* talented individuals or innovative organisations tends to be rather low (Trippl et al., 2018).

As a way of overcoming the network barriers, a new knowledge organisation may contribute to increasing knowledge flows from internal, and more importantly, external actors.

2.3.3 | Institutions

The institutional setting in which a RIS is embedded includes both formal and informal institutions, often referred to as the "rules of the game" (North, 1991).

Formal institutions

Traditionally, the promotion of already existing industries has been a common approach by which policy makers offer support to regions (Porter, 1998). This orientation can also be found in the innovation policy literature, where path dependency has been attributed to policy lock-in and risk-averse policy makers (Nauwelaers, 2011). In turn, this approach makes it difficult to adapt to new challenges, such as the oil and gas crisis. The literature on institutional failures and political lock-in has also highlighted challenges arising from inadequate policy (Woolthuis et al., 2005) or from policies strongly tied to an existing industry (Grabher, 1993). Recently, however, there has been a shift in this understanding, recognising that the maintenance of leading industries in a region is not sufficient to ensure long-term competitiveness (Asheim et al., 2011; Isaksen et al. 2019).

Informal institutions

Barriers in informal institutions can relate to norms, values, culture, and low levels of trust that hamper innovation. Problems with these aspects can lead to institutional failures (Woolthuis et al., 2005), for example, a lack of mutual trust can inhibit knowledge flow between actors in a RIS. Another informal institution is that of conventions. Isaksen (2018) conceptualise actors' behaviour according to conventions "that are implicit rules of what to do in specific situations" (Isaksen, 2018, p. 5). In a thick and specialised RIS, conventions might be built at the individual level to support the existing modus operandi, because this type of RIS tend to be dominated by conventions of its leading industries.

Another aspect of informal institutions is the notion of directionality failure. According to Weber and Rohracher (2012), the traditional system failure arguments are somewhat restrictive and incomplete. They argue that long-term transformative change requires collective priority setting, which in turn requires strategic policy. Setting a direction entails not only trying to generate innovations as efficiently as possible, but also responding to external factors such as major identified societal challenges (Weber & Rohracher, 2012), for example, the pressure for an industry to become more environmentally sustainable. To deal with directionality failure, actors must first understand external requirements, then interpret them and orient all actors in the system towards these challenges. Furthermore, under specific circumstances, alignment can be promoted by establishing shared future visions (Weber & Rohracher, 2012). This may be a challenging task, made even more challenging when the incumbent industry must alter its vision in the direction of long-term transformative change. Both conventions and shared visions are arguably tied to the concept of expectations, since conventions shared by several actors will influence the expectations and visions one has for the future development of an industry (Hassink et al., 2019).

A new or altered knowledge organisation can potentially overcome barriers relating to both formal and informal institutions, for example, by lobbying policy makers to promote new industries or to create an understanding of the new opportunities and visions they see for the region. A new perspective on an industry and how it can evolve might contribute to changing the existing conventions that have developed over time (Isaksen, 2018).

2.4 | Analytical framework

The analytical framework set out in Table 1 draws on the theoretical concepts discussed above and illustrates the typical barriers new regional industrial path development may face in a thick and specialised RIS, and the potentials a new or altered knowledge organisation may have of overcoming them.

3 | CONTEXT AND METHOD

The empirical part of the article contains a case study, which includes both a subject and an object of analysis (Thomas, 2017). The subject of the case is the centre for research-based innovation (SFI OM), while the object of analysis is the ability of the SFI OM to overcome barriers in the Agder RIS and support new regional industrial path development.

The Agder region has approximately 300,000 inhabitants and lies in the southernmost part of Norway. The core of the region is often referred to as the "drilling bay" due to the number of firms connected to the drilling division of the oil and gas industry. In 2014, 17% of the employed labour force in the western part of the region, and 10% in the eastern part, were connected to the oil and gas industry (Blomgren et al., 2015). The industry has been strengthened by the establishment of an industry cluster in 2006, which has now reached global centre of expertise[1] status (GCE Node) and consists of 100 firms connected to the industry. In addition, the region has an innovation laboratory,

TABLE 1 Analytical framework

	Barriers facing new industrial path development in a thick and specialised RIS	Examples of how a new/altered knowledge organisation can contribute to overcoming barriers in a thick and specialised RIS
Firm-level actors	Lack of knowledge, competence, and ability to create new knowledge due to highly specialised knowledge and skills already possessed	Developing and combining new knowledge for the region through infusion of new knowledge, new collaborations, further training, and creation of spinoff projects
	Different knowledge bases and innovation modes between RIS actors	Working on improving the understanding of how different knowledge bases and innovation modes affect the different actors
	Weak interaction between research and industry	Acting as a facilitator for better interaction between research and industry
Network	Networks between known or existing actors are too strong	Increasing the knowledge flow from internal, and especially, external actors
Institutions	Institutional rigidity	Creating institutional flexibility
	Formal—policy supporting the existing industry	Formal—lobbying for policy that supports other industries
	Informal—hampering norms, values, culture, and low trust. Conventions that support existing industries and lack of shared vision for transition	Informal—increasing collaboration between different actors to increase trust and understanding of the different cultures etc. Creating new opportunities by acknowledging conventions and creating a shared vision for taking the industry in new directions

university study programmes, and an SFI tied to the field of mechatronics, thus, strengthening the already existing industry.

An SFI is a policy instrument of RCN and each centre receives funding for 5 years (with a 3-year extension contingent on an evaluation). There are currently 23 SFIs located across the country. The overall aim of an SFI is to stimulate the innovation capability and internationalisation of Norwegian businesses while also contributing to enhanced quality and efficiency in the public sector. The SFIs aim to stimulate innovation through long-term research collaboration between research-intensive firms and excellent research environments. The RCN, the host institution and various partners collectively fund each SFI, with the RCN contributing 50%. The host institution may contribute with infrastructure, equipment, personnel, or strategic funding, while industrial partners usually contribute with budgetary funding or in-kind contributions. In total, the annual budget is approximately 20–30 million NOK or 2.2–3.4 million USD.

The SFI OM is a consortium of 7 research institutes and higher education institutions, 12 manufacturing companies, and 1 cluster administration, with 11 actors based in region. The Centre was established in 2015 and supports the already strong service industry for the oil and gas sector in the Agder region. At the end of 2017, there were 22 PhD candidates and two postdoctoral researchers in the Centre. The Centre's goal is to work towards autonomous offshore operations and ultimately a fully automated oil and gas platform. In addition, they aim to contribute significantly to growth and innovation in the industry, creating jobs and businesses within the target sector and beyond. According to the RNC, "patience is required" when dealing with an SFI because the required innovations may be 7–10 years away. Hence, at this time, it is difficult to do more than discuss the potential for new regional industrial path development.

The data employed in this article was collected from document studies and two rounds of interviews with SFI OM members. The document study comprises readily available information about the SFI OM and mid-term self-evaluations from five of the industry members and the Centre's management team. The first round of interviews was conducted in early 2016 and consisted of 15 semi-structured interviews with regional and national partners, each interview lasting between 30 and 90 min. Because the SFI was relatively new, the 2016 interviews are mainly used to understand why the partners joined the SFI and what expectations they had when joining the collaboration. The second round of interviews was conducted in 2019. To increase the regional focus, this round of interviews consisted of nine semi-structured interviews with leaders in regional firms and research institutions, each interview lasting between 45 and 90 min. The interview results will help to evaluate whether, and how, the SFI OM is contributing to the reconfiguration of the RIS and its potential for new path development. To ensure anonymity, the article only refers to the interviewees as industry partners (I1-I7) or research partners (R1-R11). The quotations used in the empirical analysis section are from the 2019 interviews if not otherwise stated. Table 2 provides information about the different informants, such as the type of informant, the year in which they were interviewed, and whether they are regional or not.

4 | EMPIRICAL ANALYSIS

Departing from the case, this article sets out to explore the barriers to new path development at the actor, network, and institutional levels in the Agder region—an organisationally thick and specialised RIS. In addition, the empirical analysis investigates how the SFI OM, as a new knowledge organisation, might contribute to overcoming these barriers. The analysis will conclude with a table illustrating the current situation, challenges, and potential solutions for the SFI OM to move beyond path extension.

TABLE 2 Informants in the SFI OM

Informant	Type of informant	2016	2019	Regional
I1	Industry	X	X	X
I2	Industry	X	X	X
I3	Industry	X	X	X
I4	Industry	X	X	X
I5	Industry		X	X
I6	Industry	X		
I7	Industry	X		X
R1	Research	X	X	X
R2	Research	X	X	X
R3	Research		X	X
R4	Research		X	X
R5	Research	X		X
R6	Research	X		X
R7	Research	X		
R8	Research	X		
R9	Research	X		
R10	Research	X		
R11	Research	X		

In the Agder region, as with other thick and specialised RISs, a central challenge for new path development is the lack of diverse knowledge or competencies. This becomes especially crucial in times of crisis or external shocks when changes might be necessary to maintain employment in key regional industries. In 2015, the Agder region experienced an external shock that would make new knowledge input imperative. At the same time as the SFI OM application was granted by the RCN, the oil price was halved from over 100 USD per barrel. In less than a year, the price dropped to under 30 USD per barrel. According to an informant (R2), two of the largest employers in Agder had to dismiss over 3,000 engineers, and over 6,000 were dismissed in total by SFI partners. As all of this was happening, the SFI OM was established to support the oil and gas industry. The aim of the Centre was to "contribute significantly to growth and innovation in the industry, creating jobs and business with potential both within the target sector, and beyond, such as maritime industry, with a net positive impact on society".[2] Thus, the Centre intended to improve an already strong industry, as opposed to working towards new regional industrial path development. With the crisis affecting the partners on a large scale, however, the members could see this as an opportunity to move beyond "simply" oil and gas.

4.1 | Actors

According to the analytical framework, a new or altered knowledge organisation might contribute to overcoming the barriers hindering new industrial path development by developing or combining new knowledge for the region. The SFI OM is creating knowledge within the confines of the Centre, meaning that actors outside the Centre will have no direct access to the knowledge developed. However, knowledge developed in the Centre might still contribute to new industrial path development. First,

the Centre members include the largest companies in the industry in Agder, as well as research institutes and higher education institutions in the relevant fields. In addition, these large industry partners have a buyer–supplier relationship with several smaller regional firms in the industry. Thus, knowledge developed by these large actors can potentially affect key parts of the RIS. Second, as stated in the self-evaluation provided by the Centre's management:

> Since the centre has partners which operate and compete in the same business segment, it has been decided that the research in the centre should focus on core technology, software, methods and building blocks which the companies can develop further and integrate in their internal R&D and product development processes.

Thus, the knowledge generated is generic and more readily transferable and applicable in other industries.

According to both the industry and research informants, there have been challenges regarding the development of new knowledge in the SFI OM. The knowledge developed has mainly resulted from research conducted by doctoral students and professors. When this knowledge is transferred to the industry partners, that traditionally have depended heavily on experience-based competencies for their practice, the new knowledge is incomprehensibly complex for many, rendering the research useless for the industry. The different knowledge bases and innovation modes have also affected the knowledge exchange in the Centre, causing the DUI-dependent industry to struggle with absorbing the scientific knowledge produced by the research partners. While some industrial partners would have appreciated a more easily understood version of the research, the research partners would have appreciated a higher competency level in the firms. This means that for a new or altered knowledge organisation to contribute to new path development, a certain level of absorptive capacity is required (Cohen & Levinthal, 1990) in the industry partners, along with diffusion and translation capacity within the research institutions. Finding a balance between complexity and comprehensibility within the SFI has been challenging. One research informant (R3) discussed whether the research findings should be simplified for the industry, stating:

> Perhaps we need that, or perhaps we need to raise the level of the firms when it comes to that. I am afraid that we want to be world-leading, with something complicated without having the competence or the will to do it.

At the same time, it seems as if the distance is decreasing or at least being acknowledged. In 2016, an industry partner (I3) said this about the research partners: "Some professors are king of the world and there is a lot more freedom in academia than in the industry. They don't ask if their publications are relevant for us. There needs to be more dialogue and requirements for interaction." In 2019, the same informant (I3) explained:

> Academia says, which I agree on, that we need to provide competence to extract the knowledge they provide. One answer to this is to hire the PhDs from the Centre when they are finished. However, they [research partners] should also provide some popular science, which they have already started to do.

This change in attitude illustrates how the research partners are trying to meet the industry half-way and vice versa. Recognising the importance of scientific knowledge was also highlighted by informant I4 who stated that "getting people with research experience into the industry is important. That will build

competence and create a learning organisation that can absorb and develop new technology by itself." These excerpts suggest that the SFI is moving in the right direction when it comes to acting as a bridge between the partners, facilitating easier knowledge exchange.

Another way the SFI OM can develop new knowledge is to contribute to changing the expected output from the research partners, which is primarily publications. Specifically, the SFI OM has, in collaboration with a commercialisation partner, developed a tool called Research Impact Canvas. So far, this tool has been employed by all the PhD candidates in one of the work packages of the SFI. The process has led to potential innovative ideas, which could potentially be commercialised by partners outside the centre. The potential for innovations within the SFI is seen to be enormous, but so far, most of its output has been publications rather than innovations or patents. As an informant (R2) explained:

> One % [of research] results in patents and DOFI (disclosure of inventions). I want to increase the number of patents and DOFI, but this involves dealing with the culture and mentality. For a PhD candidate, a patent process can easily take two years, but he or she needs to publish to receive a PhD.

The SFI OM has attempted to change this mentality by giving an award to everyone who presents a DOFI at the Centre's yearly conference. This creates an awareness of the commercial potential the research might have. Thus, breaking from old ideas should not be limited to new business models, but should also include new ways of using and viewing research. Table 3 illustrates the diversity of the SFI partners, which is important for the Centre to keep in mind when continuing its work in order to create an enabling environment for knowledge exchange.

Although there are some challenges involved in developing knowledge, the SFI OM generally serves the purpose suggested in the analytical framework, which is to create new knowledge for the region. One way to achieve this goal is through the development of spinoff projects. This has been an important focus for the Centre, as explained by one of the research partners: "We have many spinoff projects. Currently, the spinoff projects have received the same amount of funding as the SFI itself, and many of these spinoffs are directed towards restructuring" (R2). During the first 5 years, a total of 10 direct spinoffs and 3 related parallel projects were driven by the Centre and its partners. According to the midway evaluation, one reason to create spinoffs is to enable the industry partners to continue working with the generic technology in a confidential manner. This may also be achieved through a confidential master's thesis. This resonates with informant I4 who said they want spinoff projects "as a way of building on knowledge created in the SFI OM." The knowledge spillover occurs in both formal spinoff projects and directly with students working on assignments related to the SFI. The importance of these students is highlighted by one of the research partners: "I believe this is the best way to create

TABLE 3 Characteristics of the SFI partners

	Research partners	Industry partners
Knowledge base	Analytical	Synthetic
Innovation mode	STI	DUI
Inputs	Researchers	Technologies
	Ph.D. students	Money
		Ph.D. students
Outputs	Publications	Innovations

innovation. That master's students, and especially PhD candidates, continue their work in a firm to make it a smooth transition" (R2). So far, the SFI has been linked to 94 bachelors' and masters' theses from different universities. Even though many of the spinoffs are connected to the oil and gas industry, there have also been examples of spinoffs involving other industries; for example, collaboration with a new e-health centre at the university, to which methods developed in the SFI are applicable. Another example is the way in which the results of one of the spinoff projects contributed to a SFI OM partner becoming involved in a project to develop the first-ever zero-emission, autonomous ship.

According to several industry and research informants, the SFI OM has also contributed to the establishment of a more tangible outcome, namely, the regional Mechatronics Innovation Lab (MIL). MIL is a national centre for innovation, piloting, and technology qualifications. Thus, it contributes to developing and combining new knowledge outside the local oil and gas industry. One industry partner (I5) highlighted the importance of the interaction between regional initiatives as opposed to viewing the significance of each independently:

> It is important to understand the limitations of the SFI. The Centre focuses on a specific theme that can lead to many interesting things. However, it is important to understand that the building blocks are not always big. Thus, the interaction between clusters, MIL, the SFI and future initiatives is the important bit.

Through the abovementioned initiatives, the SFI OM has demonstrated how it may contribute to moving the region beyond path extension and modernisation. However, the potential for new path development depends heavily upon the SFI OM partners and knowledge spillover between them, because regional actors outside the SFI OM are largely denied access to "SFI-created knowledge." If partners do not see the potential advantages of sharing knowledge outside the SFI-network, when creating new or spinoff firms, the only access point for outsiders will be through information gleaned from published articles.

4.2 | Networks

As illustrated in the analytical framework, barriers at the network level often relate to networks that are too strong, resulting in a lack of new knowledge input. While the knowledge exchange between the Centre's industrial partners and research partners suffers from a lack of absorptive capacity, the knowledge exchange between the Centres' industrial partners suffers from a different problem. In Norway, most SFIs have industrial partners representing different segments of the value chain. In the SFI OM, the largest and most significant regional partners are in direct competition with each other, and the focus of the SFI OM relates to their core competencies. This was well known when the application for this specific SFI was written, and, according to a research informant, this emphasis was necessary to add weight to the application. Although this was recognised as a risk, it has created more challenges than initially expected. Two of the industry informants illustrated this when they stated: "It is restraining having competitors. It requires awareness to rise above the competition" (I2) and "I am not sure if there is anything positive about the involvement of competitors, but we have to make it work" (I3). Even though they are hesitant about sharing information in the SFI, the industry partners have maintained a strong preexisting network resulting from initiatives organised by the industry cluster. The analytical framework suggests that overcoming barriers would entail increasing the flow of new knowledge. On paper, the SFI delivers this by having regional, national, and international industry and research partners connected to the SFI. However, informants did not agree on the level of success achieved to date, in terms of new relationships and improved networks. Several informants

stated that few new relationships or networks have been created in the SFI, with one research partner asserting: "I did not expect more network building, but I think the SFI management might have" (R3). However, an industry partners explained that, through the SFI, they made new connections with people in firms they were already familiar with, thus, creating a stronger bond with those firms. This might not contribute to overcoming the barrier represented by "too strong" networks. However, the same person explained that ties to a non-regional actor can create new potential:

> There is a big company, working on many different things, and we have, via this network, met with a different part of the company, which is working on smart cities and so forth. So, there are these detours that have nothing to do with the SFI, but it makes you build connections with the people sitting there. (I1)

Another hurdle that made expanding the network difficult was the lack of ownership of some of the SFI personnel. One informant explained it thus:

> There has been a perception that the industry has not done the preliminary work to figure out how to get the most out of the SFI and this is perhaps because the personnel who said 'yes' to participating in the SFI are not the ones actually participating. (R3)

Thus, the feeling of ownership of the SFI might not be as strong as one hoped.

As described in the theory section, attracting external knowledge can be difficult in a thick and specialised RIS. In the Agder region, and in the SFI, there are several multinational corporations (MNCs) that also can influence how new networks are created. According to Aslesen et al. (2017), MNCs' involvement in global innovation networks can both stimulate and hamper path renewal in thick and specialised RISs. They can stimulate interactive learning and "loose coupling" of different units in order to combine knowledge. They can also inhibit these links, depending on the support they receive from their headquarters to explore new knowledge combinations and their levels of absorptive capacity (Aslesen et al., 2017). Although the influence of MNCs is not the main focus in this article, they might have played a role in the lack of interest in creating new networks. Even though the SFI has attracted both talented individuals and innovative organisations, it currently seems that the SFI is not contributing significantly to overcoming potential network barriers to new path development.

4.3 | Institutions

4.3.1 | Formal

The Agder region has long benefited from several policy instruments that are committed to the oil and gas sector, such as the SFI OM, the MIL and the GCE Node, as well as study programmes at the University of Agder that are tailored to the industry. This is a way of coordinating the industrial and scientific partners in the region, and it also implies that a potential new path might struggle to find policy support. Even after experiencing the effects of the oil crisis, the SFI OM did not alter its focus in terms of either overall strategy or strategies for the individual work packages. They appear to be concerned primarily with further developing the already strong industry and have not lobbied for changes. According to the analytical framework, new industrial path development would require dismantling the policy barriers that currently support path extension. Although lobbying for new policies

TABLE 4 Empirical summary

	Current situation	Challenges	Potential solutions
Firm-level actors	Creating generic technology (also applicable in different industries)	How to transfer the technology to other industries	Increase the focus on cross-industry spinoffs and increase innovation output in terms of patents etc. (not only publications)
	Knowledge creation happens mainly within the centre	How to share knowledge with external partners while adhering to the consortium agreement	Create new industrial practices, increase diffusion through bachelor's/master's/PhD thesis'
	Mismatch when transferring analytical knowledge from research partners to industry partners working mostly with experience-based knowledge	Lack of absorptive capacity with industry partners and lack of diffusion and translation capacity with research partners	Use the SFI to bridge the two spheres by increasing the number of workshops facilitating compromise
	Creation of spinoffs both within and outside the industry	Increasing the number of cross-sectorial spinoffs	Increase involvement with different industries through spinoffs
Networks	Few new networks have been created	Increasing extra-regional network links for new input	Stimulate network building within the Centre
Formal institutions	Policy instruments are committed to the incumbent oil and gas industry	Gaining policy support for initiatives connected to other industries	Create an awareness of the vulnerability of promoting one industry and start lobbying for more diverse policies
Informal institutions	Mostly unchanged conventions, both within firms and the SFI, and an unchanged vision and direction for the industry	Changing the mindset to diversify the long-established vision pertaining to the oil and gas industry	Increase meetings and discussions about future endeavours and cross-industrial thinking

is not the main priority of the SFI, one informant recognises the challenges the industry is facing and explained the potential need for new path development:

> Personally, I see the oil and gas industry struggling in the future. There will be a need for restructuring, and these are some of the region's largest employers so this can either become a really painful or a slow transition. I see some firms that have started on this slow transition, but others will go down swinging. (R2)

If the SFI firms that are transitioning gradually are to experience the best conditions for success, they will have to reorient their approach towards policies that support a more diverse industrial structure.

4.3.2 | Informal

The barriers resulting from informal institutions in organisationally thick and specialised RISs involve conventions at the regional level, such as an inherent support for the existing industry. As noted above, the formal strategy was not altered after the crisis in the oil industry. Some informants have attributed this to thorough analysis conducted in the application process and the resulting strategic direction. According to one informant (I4), the selected themes were forward-thinking in that they related to data and automation, instead of specific technology or products. These themes contributed to making the work conducted in the SFI more generic and, thus, potentially applicable to other industries. However, the SFI has clearly not contributed to overcoming the barriers resulting from informal institutions, since industry partners show no interest, to date, in moving in new directions. For this to occur, more people would have to speak up, such as the informant above who reflected on the future of the industry. The need for transition, expressed by this informant, highlights the need to discuss, not only system failures, but also transition failures, such as directionality failures. Until various actors realise the need for greater changes and a long-term strategy based on new and shared visions, this directionality failure will persist.

Table 4 summarises the empirical analysis, illustrating the current situation, the challenges, and the potential solutions for moving beyond path extension or path modernisation.

5 | CONCLUSION

This article aims to contribute to a better understanding of the barriers inhibiting new regional industrial path development. It addresses barriers in all three aspects of a RIS: actors, networks, and institutions. In addition, the article presents an analytical framework for explaining these barriers and exemplifies how a new knowledge organisation might contribute to overcoming them.

Much has been written about industrial and regional change (Asheim & Gertler, 2005; Fagerberg, 2005; Martin, 2010; Martin & Sunley, 2006), but there has been less focus on the barriers to achieving the desired change. Directionality failure (Weber & Rohracher, 2012), as an informal barrier, is pertinent in this case because the oil and gas industry is facing increasing pressure to become more environmentally sustainable.

While most of the barriers identified in the analytical framework can be recognised in the case study, not all ways of overcoming the barriers have been identified. On the actor level, the SFI has shown signs of overcoming barriers by creating new, generic knowledge (applicable to other industries), and thereby reducing the barrier of knowledge being too specialised. Although the generic

nature of this knowledge might be positive for future path development, working in an SFI including competitors and partners from two different spheres (research and industry), is challenging. Much time and effort has gone into building trust and sharing knowledge, and the need for absorptive capacity on both sides has proved to be important.

Regarding networks, it seems the potential for the SFI OM to infuse the region with new knowledge through new intra- and extra-regional linkages is relatively high, due to its structure, representing both research and industry. However, in practice, few new linkages have been created.

Since the industry incumbents in the RIS are overwhelmingly oil and gas service companies, both formal and informal institutions are rigged in favour of this industry. Hence, in practice, there has been no clear effort to lobby for changes in policy, nor to work towards changing informal institutions within the RIS. A few informants see the need for branching out of the sector, but they are in a minority.

The lack of initiative to overcome barriers to new regional industrial path development is evident in Table 4, illustrated especially by the column representing challenges. However, the table also discuss potential solutions, highlighting the need for cross-industry thinking, network building, and an increased focus on the industry's vulnerability, encouraging a need to lobby for new policies. By focusing on the potential solutions, the SFI OM can contribute to overcome barriers for new regional industrial path development.

The article also contributes to a deeper understanding of SFIs as a policy tool. The composition of an SFI offers different possibilities in terms of outputs and how the RIS might benefit. In SFIs that represents a complete value chain, with no competitors, a concrete product might be the result. In these cases, knowledge from an SFI might be difficult to share with other RIS actors outside that specific value chain. However, in SFIs such as the SFI OM, the knowledge created is generic. In these cases, the RCN should emphasise the importance of sharing knowledge with external actors, and perhaps also stimulate this knowledge transfer. One of the industry informants (I1) in SFI OM explicitly stated that the process industry in the Agder region could benefit from the knowledge developed in the SFI. However, this informant was unable to propose clear mechanisms for how this could be achieved.

Although this article examines an organisationally thick and specialised RIS, the barriers might be similar in thick and diversified RISs and thin RISs. Future research should study barriers in different RISs to examine how new knowledge organisations can contribute to overcoming them. In addition, the influence of MNCs should be examined further, building on the work conducted by Aslesen et al. (2017). For policy purposes, research comparing SFIs with different compositions (e.g., competitors vs. value chain partners) could provide useful insights for continuing work relating to SFIs and similar policy tools.

DATA AVAILABILITY STATEMENT

Research data are not shared (due to confidentiality).

ORCID


Nina Kyllingstad https://orcid.org/0000-0001-8563-2119

ENDNOTES

[1] An industry cluster programme organised by Innovation Norway, Siva (The Industrial Development Corporation of Norway) and The Norwegian Research Council.

[2] From the SFI Offshore Mechatronics web page.

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