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Greening of regional industrial paths and the role of sectoral characteristics: A study of the maritime and petroleum sectors in an Arctic region

Abstract

Recent studies on regional industrial path development call for new perspectives and studies of how a region's endogenous and exogenous processes (e.g. networks, capital, knowledge) influence its industries, and, more recently, the greening of those industries. To this end, recent research has focused on increasing our understanding of the roles of firm- and non-firm agency and multi-scalar dynamics (e.g. value chains, national and global regulations). However, the literature has naturally tended to focus more on territorial dynamics (e.g. agglomerations, clusters, regional innovation systems) than on the role of sectoral characteristics to explain regional industrial path development and regional industry greening. To address this, we have developed a framework built on the sectoral innovation systems literature to provide a better explanation of the role of sectoral characteristics in regional industrial path development. We argue herein that the greening of regional industrial paths can be strongly influenced by sectoral characteristics (e.g. standards, markets, technological solutions, laws, regulations), and not merely by territorial characteristics. Our theory-based argument is practically exemplified by an investigation of how a new green technology, onshore power supply, has influenced the greening of two industries (i.e. maritime and petroleum) in the rural Arctic region of northern Norway.

Key words

Regional path development, green regional development, sectoral innovation systems, path development, rural, restructuring

Introduction

The evolution of regional industries, typically conceptualized as path development (Martin, 2010), has been of major interest within economic geography, particularly research drawing on evolutionary theorizing (Asheim et al., 2019; Boschma and Frenken, 2006; Hassink et al., 2019). Economic geography researchers have been devoted to explaining the spatiality of industrial development processes; thus, the regional level has received much theoretical, analytical and empirical attention. However, the evolutionary perspective has also been criticised for "regional fetishism" (Binz et al., 2016; Essletzbichler and Rigby, 2007) and for paying little attention to how regional industrial activity is interwoven in complex multi-scalar interplays (Isaksen and Trippl, 2016). Consequently, recent studies have focused on explaining regional industrial path development by considering more explicitly both multi-scalarity and agency (i.e. actions or interventions performed by firm and non-firm actors) (Grillitsch and Sotarauta 2020; see also e.g. Binz et al., 2016). Unsurprisingly, this literature has focused on regional characteristics and dynamics, and how regional industries are influenced by endogenous and exogenous circumstances (Afewerki, 2020; Binz and Truffer, 2017; Frangenheim et al., 2020; MacKinnon et al., 2019; Njøs et al., 2020; Trippl et al., 2017). However, we submit that the role of sectoral characteristics has been granted limited attention towards explaining regional industrial path development. We argue herein for theoretical and conceptual approaches that consider more explicitly how economic actors are also embedded in sectoral dynamics—meaning that firms' sectoral characteristics should have greater prominence in regional industrial path development analyses. To achieve this, we build on the sectoral innovation systems (SIS) literature to incorporate insight on sectoral characteristics, informing the regional industrial path development literature, and, more specifically, the emerging topic of greening of regional industry paths.

Our goal is to contribute a discussion of the spatio-sectoral interplay influencing firms and regional industries. First, we discuss the regional industrial path development literature, before exploring the SIS approach, a literature devoted to analysing and explaining sectoral characteristics and differences (Malerba, 2002, 2005). We argue that sectoral characteristics are important for expanding discussions of regional industrial development and, in this case, greening of regional industrial paths. This theoretical and analytical discussion is then illustrated by an empirical investigation of the implementation of a new green technology (onshore power supply [OPS]) by firms in two sectors (maritime and petroleum) in northern Norway's rural Arctic region Troms-Finnmark. To meet this goal, we address two research questions. Our theoretical research question is: How can the SIS concept inform analyses of regional industrial path development? Our empirical research question is: How do the sectoral innovation systems of firms operating in the maritime and petroleum sectors of northern Norway influence greening of the region's industrial development paths?

Theoretical background

Herein, we treat evolutionary economic geography (EEG) as a literature stream within economic geography, which includes different theoretical strands. These vary from an evolutionary approach focused on variety and diversification of regional industrial compositions (Boschma and Martin, 2010; Boschma and Frenken, 2006) to regional innovation system approaches that attend to the evolution of the support systems influencing regions' innovation and industrial transformations. We take a position within the latter, treating regional industrial path development from a systems perspective, which should be explained by investigating the role of firms and non-firms within a regional context (Isaksen et al., 2018). Linked to this, regional industrial path development can be approached by investigating pre-existing industrial and institutional systems and how these shape current and future industrial trajectories (Isaksen and Trippl, 2017). Hence, the role of historical

developments, contingencies and territorialized capabilities are central to explaining regional industrial development processes (Martin and Sunley, 2006, 2010).

Regional industrial trajectories can be classified into several categories, e.g. 'path extension', 'path diversification' and 'path creation' (Grillitsch et al., 2018), contributing to our understanding of how regional industries transform in time and space. Linked to this, the literature has been inspired by evolutionary theorizing and is increasingly focused on not only regional preconditions for industrial development (e.g. explanations of what makes regions innovative), but also how regional industries are transformed (Asheim et al., 2019). To explain industrial transformation, focus is increasingly devoted to the roles of (firm- and non-firm) agency and multi-scalar dynamics (Binz et al., 2016; Hassink et al., 2019). Hence, while traditionally concerned with explaining regional preconditions for industry development and innovation (e.g. descriptions of regional innovation systems and their set-ups) (Doloreux and Porto Gomez, 2017), recent research has contributed insight into how interplays between a region's endogenous and exogenous processes influence industrial development (Coenen et al., 2015; Dawley, 2014; Isaksen and Trippl, 2017).

Sotarauta (2016) defined agency as 'actions or interventions by actors producing particular effects'. Using this definition, changes to a regional industry path require purposive actions by actors within or beyond the firm (Isaksen et al., 2018). For instance, Simmie (2012: 769) stated that the creation of new green paths 'requires social action by knowledgeable pioneering individuals, universities, companies and/or governments'. Thus, inspired by the work of Garud and Karnøe (2003), the transformation of regional industrial paths presupposes efforts by more than one or two firms—it requires a multiplicity of actors (Binz et al., 2016; Dawley et al., 2015; Sjøtun, 2018; Steen and Hansen, 2018). For instance, Isaksen et al. (2018: 52) argued that changes can be initiated by 'system level' agents through 'action[s] or intervention[s] to change the functioning of the regional support structure for innovation' or by firm actors whose actions lead to changes in the support system. Herein, we are

particularly concerned with the latter: how firms contribute to changing regional industrial development paths and, within our empirical case, how firm-led implementation of green technology can lead to changes in a region's existing industrial path.

Consequently, we consider regional industrial development to be influenced by 'the nexus of intentional, purposive and meaningful actions of many actors, and the intended and unintended consequences of these actions' (Grillitsch and Sotarauta, 2020: 708); this topic is also highly relevant to investigating the greening of industries in a region (Jolly et al., 2020). However, we note that actions can be performed by actors both within and beyond the region (Miörner and Trippl, 2017; Njøs et al., 2017; Trippl et al., 2017). This has been a key point in recent research stressing how factors exogenous to a region (e.g. national regulations, global commodity markets) can stimulate innovation and alter regions' existing industrial paths (Isaksen and Trippl, 2017; Miörner and Trippl, 2017; Njøs et al., 2017; Trippl et al., 2017). For example, non-core regions are sometimes better off when stimulating couplings between exogenous and endogenous actors, rather than focusing on intraregional linkages in isolation (MacKinnon, 2011; Miörner and Trippl, 2019; Nilsen, 2017). This finding also pertains to greening of regional industrial paths (Grillitsch and Hansen, 2019). Similarly, a comprehensive review of the scientific work on green industrial development found that 'multi-scalar perspective is necessary in order to fully comprehend green growth and barriers' (Capasso et al., 2019: 396). Another example of this is the work by Binz et al. (2016), who argued that conjoining regional capabilities and global development processes is important for explaining industrial development processes. Similarly, Njøs et al. (2020) found that interconnections between regional industrial development paths and more "generic" technological characteristics matter when explaining regional industrial path development and the greening of regional economies. In addition, a growing body of literature on socio-technical transitions argues that greening of industrial activities in regions should be

approached by investigating their multi-scalarity (Coenen et al., 2015; Grillitsch and Hansen, 2019; Hansen and Coenen, 201; Njøs et al., 2020).

However, similar to the "traditional" regional industrial path development literature, the emerging literature on the greening of regional industries ascribes primary importance to understanding how these evolve based on intersections between endogenous and exogenous processes, and how such processes influence green innovation and the emergence of green industrial activities (Capasso et al., 2019). In other words, the approach generally builds on the current regional industrial path development literature (Grillitsch and Hansen, 2019).

This literature has investigated how different industries evolve within a region as a result of endogenous and exogenous processes (Hassink et al., 2019), and has focused on, e.g. key actors, networking and knowledge dissemination (Figure 1). However, though this topic was acknowledged in early EEG theorizing, e.g. see seminal work by Boschma and Frenken (2006: 288–289)—both theoretically and analytically—less attention has been granted to incorporating sectoral characteristics to explain regional industrial path development and accompanying analytical frameworks (Moodysson and Zukauskaite, 2014). Our thesis is consistent with the recent argument by Frangenheim et al. (2020), that the EEG literature should consider more thoroughly how the characteristics of different industries within a region positively and negatively influence each other. We submit that in addition to understanding geographical circumstances, we must also better understand the role of sectoral characteristics in influencing regional firms and industries. This ties in to Bathelt and Li's (2014: 593) claim that:

> In fact, although evolutionary approaches are often based on a firm perspective, the actual analysis addresses aggregates, such as regional structures and developments, and derives general statements about, for instance, the persistence of regional distributions.

Sectoral characteristics and regional industrial path development

Within the EEG literature, many have investigated regional industries without providing integrated understandings of how sectoral characteristics can be incorporated analytically to better explain regional industrial path development, evolution and transformation. For instance, considerations of firms' sectoral belonging and sector's inherent characteristics has generally been an afterthought to their territorial embeddedness. Figure 1 offers a visualization of this approach to regional industrial path development.

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Figure 1: A simplified illustration of the EEG approach. Different coloured circles illustrate actors' sectoral orientation (e.g., petroleum, maritime, biotech, etc.), whereas the lines indicate linkages between the actors. Dotted lines represent extra-regional linkages.

As a nuance to this, Binz and Truffer (2017) illustrate how (green) innovation activities differ between industries in relation to knowledge, markets, legitimation and investment. This has aided researchers by explaining how geography matters differently to different sectors and technological development processes. However, territorial approaches such as regional innovation systems' strong focus on regional settings risk overlooking the importance of sectoral characteristics and the role of sectoral dynamics in explaining observed outcomes (Smith and Romeo, 2016). For instance, Moodysson and Zukauskaite (2014: 135) discussed how regional innovation policy is typically insensitive to the sectoral specificities of firms located within the same region. They found that the scope of regional policies they investigated in Scania, Sweden was relatively similar across industries as diverse as the media, food and life sciences:

> [The policies] follow the commonsense formula for cluster organizations derived from the literature. The main focus is geared towards promoting the formation of coherence and collaboration in local networks, especially between industry and academia. The rationale for this strategy is that such networks are assumed to promote knowledge spillovers, innovation and the formation of new companies.

Similarly, in their study of greening in three different clusters within the same region, Sjøtun and Njøs (2019: 2423) found

> a commonality for all three cluster projects in that they wish to contribute to the reorientation of the respective industry clusters. However, […] there is not necessarily a 'joint regional expression' to pursue green reorientation of regional industries. This, we believe, has as much to do with sectoral characteristics in which the clusters take part (petroleum, marine and maritime) as with how the cluster strategies have been affected by cluster policy and other policy domains.

Similarly, building on the SIS concept in their study of green innovation in California, Chapple et al. (2011) showed that green innovation varies widely between sectors, meaning that there is heterogeneity between firms and sectors within the same region (see also Faber and Hoppe, 2013; Makkonen and Inkinen, 2018; Oltra and Saint Jean, 2009). The SIS concept aims to provide a 'multidimensional, integrated and dynamic view of sectors' (Malerba, 2002: 248). Thus, SIS focuses on economic competitiveness through investigation of firms and sectors, where firms, including users and suppliers, are the key actors in the system (Coenen and Díaz López, 2010). A SIS is understood as

> a set of products and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products. A sectoral systems [sic] has a specific knowledge base, technologies, inputs and demand. Agents are individuals and

> organizations at various levels of aggregation. They interact through processes of communication, exchange, co-operation, competition and command, and these interactions are shaped by institutions. (Malerba, 2002: 247)

This approach necessarily emphasises that firms are unique and that there is heterogeneity both within and between systems; for example, in terms of firm organisation, network constellations, research and development (R&D) intensity, dominant technology solutions, markets and demands. The three main building blocks in a system are: knowledge and technology, actors and networks and institutions (Malerba, 2005). It has been argued that

> Heterogenous firms facing similar technologies, searching around similar knowledge bases, undertaking similar production activities and "embedded" in the same institutional setting, share some common behavioural and organisational traits and develop a similar range of learning patterns, behaviour and organisational forms.

For instance, in the maritime industry, specific laws and regulations influence involved firms, in addition to demand conditions, established technology solutions, practices, routines, etc. (Steen et al., 2019).

Thus, the SIS concept is explicitly directed towards understanding market and non-market interactions, while the regional path development literature is focused mainly on the latter (Martin et al., 2019). SIS research focuses on artefacts and activities within and between firms and other organisations; in addition, and consistent with the evolutionary focus on routines and expectations, SIS considers the role of institutional settings towards explaining differences between sectors (Malerba, 2002). Institutions (i.e. "the rules of the game") can include standards, labour markets and regulations; which institutions are ascribed importance varies between systems and is a matter of empirical enquiry. Similarly, the regional industrial path development literature also incorporates understandings of institutions and how they

influence industrial development, but focuses primarily on regional settings (Isaksen and Trippl, 2016; MacKinnon et al., 2019).

Table 1. Comparison between the regional industrial path development and sectoral innovation systems literatures

	Unit of analysis	**Main explanatory factors**	**Focus on explanation for green industrial development**
Regional industrial path development literature	Aggregated regional economic activities; regional innovation systems and dynamics	Regional particularities; practices, regional institutions, activities and industry compositions	Regional industrial dynamics
Sectoral innovation systems literature	Primary: Firms Secondary: Other actors Multi-scalar economic activities	Knowledge and technology; actors and networks; institutions	Sectors and their characteristics; geographically insensitive

Hence, the SIS concept emphasises the role of firm agency and how this is supported by surrounding actors belonging to the same sectoral systems. This provides a

> potential to connect a micro-level theory of firm behaviour with system dynamics. This yields potentially important insights on the level of individual actors' strategies and behaviour, including networking behaviour and impact (Coenen and Díaz López, 2010: 1156).

As should be clear from Figure 1 and the discussion above, we are concerned herein not with regional industrial dynamics *or* sectoral characteristics, but rather, their interconnection, i.e. spatio-sectoral interplays (Figure 2). This means that firms are understood as "embedded" in the sense that actors perform actions and make decisions that are influenced by their territorial and sectoral belonging. In other words, how a path evolves and how this evolution is influenced by agency results not only from individual actions, but how adjacent actors, both in a region and a sector, respond (Isaksen et al., 2018). This ties in with the notion of "embedded agency" discussed by Garud and Karnøe (2003: 281), who argue that 'actors' generative impulses are shaped by the very inputs that they offered'. However, it is important to note that actors can deviate from existing patterns to trigger changes in their environment; in other words, they can influence the "inputs" (Garud and Karnøe, 2001). If such "deviations" influence broader regional industrial activities, then it is also necessarily required that several and differing actors "respond" to such novel ideas or initiatives in a supportive fashion if it is to result in wider changes to regional industrial development paths. However, this implies that actors in the same context can also "block" new initiatives (Grillitsch and Sotarauta, 2020; Steen and Hansen, 2018).

< FIGURE 2 IN HERE >

Figure 2: A simplified illustration of our SIS-informed analytical approach. Different coloured circles illustrate actors' sectorial orientation, whereas the lines represent linkages between the actors. Dotted lines represent extra-regional linkages.

Next, we illustrate our theoretical argument with a practical study of maritime firms in the rural Arctic region of northern Norway. This empirical analysis focuses on the interplay

between regional and sectoral characteristics of the investigated firms, and how this is connected to the (potential) greening of two regional industry paths.

Methods, data sources and background

Consistent with our discussion above, it would be reasonable to argue from a territorial innovation system perspective that there would be a "joint" response from firms within the same region to the greening of regional industrial paths. Hence, to illustrate the SIS-informed approach described above, our empirical focus is on one technological solution (i.e. OPS) in one region (i.e. Troms-Finnmark, in northern Norway), to investigate firms operating in two adjacent sectors (i.e. maritime and petroleum). The aim of this empirical investigation was to reveal intersections between territorial and sectoral characteristics, as well as how firms respond to—and possibly change—their modes of operation based on spatio-sectoral dynamics.

We investigated firms in the maritime and petroleum sectors, within the same rural region. We believe rural regions are particularly relevant geographical settings for illustrating the interplay between regional and sectoral characteristics to explain the greening of regional industry paths (Isaksen and Trippl, 2017). Several studies set in non-core regions have demonstrated how regions outside metropolitan clusters tend to lean on exogenous sources for regional industrial path development (Hassink et al., 2019; Isaksen and Trippl, 2017; MacKinnon, et al. 2019; Nilsen, 2017). Furthermore, it has been argued that the role of actors and their agency is particularly relevant to both industrial development (Tödtling and Trippl, 2005) and green regional development (Grillitsch and Hansen, 2019) in rural regions. Studies by Jakobsen and Lorentzen (2015) and by Fitjar and Rodríguez-Pose (2020) have also shown that, at least in Norway, firms in rural areas collaborate extensively with extra-regional actors. Interestingly, they also show that rural locations are characterised by more innovation,

including green innovation (Aarstad and Jakobsen, 2020), than has hitherto been acknowledged in the literature (Eder, 2019).

Similar to the notion of "tracing the path" (Pike et al., 2016), SIS argues for "history-friendly" methodologies that can grasp the evolutionary processes underpinning observable phenomena (Malerba, 2005). Our study is built on a combination of qualitative analyses and comparisons among selected firms, organisations and industry sectors. We aimed to examine how firm agency is influenced by regional and sectoral characteristics. Consistent with the path development literature and SIS, we also focused on non-firms towards comprehending the agency of firm-actors. To this end, we conducted 36 interviews with different stakeholders in the investigated region; among these, 25 were with firm representatives (8 in the maritime sector and 17 in the petroleum sector). It should be noted that this study was carried out in a peripheral region of northern Norway. This geographical context influenced respondent selection for our case study. Two firms have attempted to implement OPS in this region. Though a few other firms have signalled an interest in OPS implementation, none moved from the idea stage to initial planning during our data collection period. One firm that planned and implemented OPS belongs to the petroleum sector, and another to the maritime sector. Most interviews were carried out in the former, with only eight in the latter, primarily because of a lack of firm variety in the region's maritime sector. In addition to the firms involved in the petroleum and maritime sectors, we interviewed seven policy actors in Troms-Finnmark's county administration. To build a stronger empirical foundation, we also interviewed four county administration politicians.

Approximately two-thirds of the interviews were recorded and transcribed. For the other interviews, we took notes regarding the most important information during and immediately following. In addition, document studies of public policy notes and white papers

addressing the empirical context were an important supplement to the interviews. Interview data were sorted, interpreted and analysed with respect to the theoretical discussion above.

Examining greening of two regional industrial paths in northern Norway

In this section, we investigate the implementation of OPS in two Troms-Finnmark region industries. First, we present the region and the technological solution, before discussing the maritime and petroleum sectors. Following these descriptions, we analyse the cases in light of the theoretical discussion above.

About the region

The investigated region is sparsely populated, with only one city of more than 25,000 inhabitants. The Arctic climate is harsh and characterised by large distances between economic actors and their support systems. Specifically, the region has peripheral characteristics and has historically been economically disadvantaged. The northernmost part of the region (Finnmark) is the largest and least populous of the counties in northern Norway, with 74,000 inhabitants dispersed over 46,000 km^2. The region's long, narrow geography creates long internal distances and related climactic, economic and cultural differences. Thus, the sea as a maritime corridor has been an important transport route within the region. The region is among Norway's least prosperous, and has been a regional policy target. While the southern part of the region is strong in fisheries and includes universities and administrative bodies, the northern part hosts several industry types that depend on natural resources. Oil and gas, mining, aquaculture, fisheries and reindeer herding are its most important industry sectors.

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About the technology

Nitrogen oxide (NO_x) emissions from a large cruise ship at quay for 8 hours correspond to the annual emissions from approximately 700 passenger cars. OPS technology provides electrical shore power for these vessels. To power vessels at berth, additional infrastructures both onshore (port side) and onboard ships are required, as electrical power from onshore grids is incompatible with vessels' voltage, frequency and earthing. The onshore grid frequency often deviates from the ship-board frequency (Interview data). Globally, most ships operate with an ongoing grid frequency of 60 Hz; most European ports operate at 50 Hz, and thus require expensive frequency conversion. Furthermore, safety features need to be integrated, all of which are standardised.

The question of whether OPS reduces local emissions, and can thus improve air quality around high-traffic ports, depends on the energy sources used for the OPS system. If OPS is fuelled by non-renewable energy sources like oil, gas or coal, OPS in itself will hinder greening of the sector in question. However, OPS is advantageous in Norway due to the availability of renewable hydropower as an energy source (Opdal and Steen, 2012). Hydropower accounts for 96% of production capacity in Norway, and Norway is the seventh largest hydropower producer in the world, with 1500 small and large hydropower stations distributed across the country (Ministry of Petroleum and Energy, 2020).

> According to calculations, OPS units will be able to reduce CO_2 emissions from six tons per day. This applies to Norway, where hydropower is used to source the grid with energy (Interview data, Norsea).

The maritime sector

A key international aim within the maritime sector is to become greener and reduce ship emissions. The sector reached an important milestone in 2018, when the CO_2 strategy was

adopted by the United Nations Maritime Organization (Maritimt Forum, 2021). The Norwegian maritime industry has been the driving force for this adoption, committing to reducing 2008-level emissions by 50 per cent by 2050. Part of this strategy is reducing emissions when ships are at port. This Norwegian maritime strategy is thought to carry prodigious potential for a "green shift" (Ministry of Business and Trade, 2015). The government has ambitious environmental goals for the maritime industry: "a green shift will help to strengthen value creation in the industry and provide a competitive advantage". The maritime industry now faces a possible "technology shift", implying that new energy carriers and technologies (e.g. battery, biogas/diesel, hydrogen, hybrid solutions) may replace conventional fossil energies (Sjøtun, 2020; Steen et al., 2019).

The maritime sector consists of several sub-sectors, including shipping, maritime services, offshore engineering and ports. In addition, multiple services are related to these core activities (e.g. R&D, finance, brokers, tech) (Reve and Sasson, 2012). Thus, the maritime sector incorporates a broad spectrum of actors, from knowledge-intensive products and services to terminals and storage services. Work towards developing the Norwegian maritime industry illustrates that its history as a maritime nation, including early era seafaring, has played a role in its evolution (Reve and Sasson, 2012). Many risk-taking ship owners and investors have also added value to the sector's emergence, contributing their effort and force of will to its development. Several yards and ship equipment manufacturers with innovative technologies have created a dynamic environment for renewal within the sector. Interplay among ship owners, shipyards and designers has created an especially favourable environment for knowledge spill-over and diffusion of new technologies. Thus, for decades, the maritime sector has been a major technology driver within Norwegian industry (Reve and Sasson, 2012; Steen and Hansen, 2018). The sector's innovations have been both technology- and capital-intensive, leading the way for vertical integration in the value chain. Further,

innovation activity has been concentrated among a few lead firms where technology development and manufacturing has been agglomerated in strong, international-leading clusters. One goal for reducing the Norwegian maritime sector's climate footprint is to reduce transportation emissions by up to 40% from 2005 to 2030 (Ministry of Climate and Environment, 2017). Within the maritime transportation sector, the government aims to support commercialisation of a greener, more climate-friendly fleet (Ministry of Climate and Environment, 2017). This is one example of institutional change within the sector. The maritime sector in Troms-Finnmark consists mainly of activities connected to fisheries and coastal transport in general. In recent years, maritime activities have increasingly been aimed at offshore and maritime operations in Arctic conditions. Approximately 4,000 people are employed within the maritime sector in Troms-Finnmark (Maritimt Forum, 2020).

The petroleum sector

The petroleum sector and related industry activities have been crucial to Norway's economic growth and for financing the Norwegian welfare state. For over 40 years, the sector and its activities have added around 1,560 billion US dollars to Norway's GDP. The first oil discovery was in 1969, after which, Norway's ambition was building a Norwegian supplier sector to serve the oil and gas resources on the Norwegian continental shelf (NCS), resulting in an institutional framework in which the government rents licences to oil companies and 78% of their income is eligible for Norwegian state taxation. The total net cash flow from the petroleum industry was NOK 257 billion in 2019, and has been estimated at nearly NOK 87 billion in 2020. Actors and networks in Norway's supplier industry have been world-leading in subsea and drilling activities, and the sector has contributed to the development of knowledge and technology sold on the global market. Actors and networks have agglomerated in southwest Norway, though it has moved further north and is now planning entry into the Arctic. The Troms-Finnmark region was introduced to the sector 40 years after

its initial start-up in southwest Norway, making it a "latecomer" compared with western Norway. Hence, the case study region consists of three oil and gas projects, with 3,800 employed in the region's sector. However, the wider economic impacts of the three projects involve purchases from a range of manufacturing and service sectors within the region.

Next, we describe how regional firms have worked to implement OPS, separating firms in the maritime and petroleum sectors to investigate the roles of regional and sectoral characteristics in explaining efforts to implement a green technology solution.

OPS implementation in two regional industry paths

> A large cruise ship that is docked for 8 hours emits as much NO_x as 700 passenger cars driving 550 kilometres (Interview, Tromsø Port Director).

This quote describes Tromsø Port, a company with 8,737 ships docked, 1.2 million total tonnage and 1 million people traveling through annually. Thus, it is logistically important and has multiple business areas (i.e. cruise traffic, fisheries, logistics, offshore). OPS is often presented as an easy fix by politicians and within the public sphere. However, while the OPS initiative has the potential to stimulate greening of the regional maritime industry, realising this requires activities involving a broad range of actors. The first issue is the role of infrastructure (or, to use SIS terminology, knowledge and technology influencing the sector), especially the necessary installations and investments both onshore and on the ships. The R&D director at the local harbour in Tromsø stated that

> The question of OPS is a question of having the same equipment in use at the harbour, and for the boats as well. A ship is not a ship when it comes to plug-ins. This makes it a challenge (R&D Director, Tromsø Harbour).

The role of actor and network heterogeneity in the maritime sector, and among the involved firms, is highlighted in this quote as a challenge to implementing OPS. As mentioned above, the harbour docks over 8,000 ships of differing sizes and shapes each year. Thus, creating a unified, standardised system (e.g. plug-ins) will require an international legislative framework within the sector (sector-specific institutional change) upon which all actors can agree and implement. The sector is highly internationalised and globalised, with ships belonging to firms from a broad range of continents, making such efforts highly challenging.

Another OPS issue is also linked to materiality (i.e. technology): supplying enough power to the harbour to meet the needs of a robust infrastructural power grid. The question of infrastructural endowments is related to how electric power can be effectively transmitted across grids. The existing grid has a specifical, limited capacity to transport needed electric power supplies to both firms and the local community; thus, a more robust infrastructure is needed to meet OPS capacity. This again ties into the SIS emphasis on dominating technology and knowledge within a sector and how this influences development processes. As emphasised by the director of Tromsø harbour:

> Based on the existing infrastructure, we could not use OPS today even if we had the equipment locally. The infrastructure grid is of limited capacity and the hospital and university would have to be excluded from the grid in order to supply the biggest cruise ships with OPS (Harbour Engineer, Tromsø Harbour).

Investments and costs are highly relevant, where in the case of Tromsø harbour, the price tag for OPS is more than 10 million Euro (interview data). However, according to a 2016 report, such investments can pay off financially (DNV, 2015). As the port infrastructure is built up and investment systems begin to function, costs will be passed on to the shipping

industry itself. The situation today is that most Norwegian ports, including Tromsø, are owned by municipalities and lack available capital. In other words, the sector's institutional set-up challenges OPS implementation, and both firm- and non-firm actors must cooperate to finance technology implementation.

In sum, this case demonstrates that the maritime industry's knowledge and technology (e.g. infrastructural set-up), actors and networks (i.e. existing firms and their practices) and institutions (i.e. the 'set-up' of the sector) influence how OPS is implemented, and as illustrated, that this implementation is hampered by both sector heterogeneity (i.e. ship plug-ins) and infrastructural and investment costs to public-owned ports. The question of grid capacity also hinders OPS implementation in this case, emphasising that if electrification is an answer to greening of the region's industry, changes are needed linked to, inter alia, actors, knowledge and institutions, in addition to infrastructural developments.

In contrast to the region's maritime path, the petroleum path has experienced success in implementing OPS. This can be explained by beneficial sectoral dynamics, in which the oil producer Eni S&P has played an especially dominant role driving technology implementation. Eni S&P is a major player within the NCS, with active production and exploration by 39 countries (interview data). It operates the first oil field in the Norwegian part of the Barents Sea, Goliat, and is based in the Arctic Operation lead office in Hammerfest, a town in the northernmost region of Norway. Downscaling the oil and gas industry in southern Norway and parallel up-scaling of the industry in the Norwegian Arctic, due to resource scenarios, has created a new regional offshore cluster through path importation and foreign direct investments in the region, supported by the regional innovation system (Fløysand et al., 2016). This cluster draws on several projects off the region's coast and has created approximately 1,100 new jobs for the region (Nilsen, 2019). The sector is the most economically profitable in the nation, in terms of both tax income and jobs. Thus, the offshore

sector attracts a large amount of capital, followed by highly skilled employees. Increased social and environmental pressure on the offshore sector to become "greener", an example of institutional change, has played an important role in Eni S&P bringing regional actors together in 2017 to discuss OPS as an initiative:

> The sector can never be green as such, as we produce oil and gas, carbons which produce high emissions both in producing and in use. However, we can do something to reduce our impact (Interview, Eni).

In partnership with private firms exogenous to the region, Simon Møkster and energy companies, Eni funded OPS implementation in 2018. This implied that ships carrying goods for the oil and service industries (i.e. companies within drilling, sub-sea and mooring) could use OPS at the harbour starting in 2019. The role of funding was never seen as a challenge that would stop implementation of this infrastructure:

> When we decided to develop the infrastructure, we soon accepted the cost and all of the partners agreed on the necessity of this initiative. Everything comes with a price (Communication Director, Energy company).

> We have the experience of working efficiently together with our private national partners within the same sector (Interview Eni).

When explaining OPS implementation, a company representative stated that:

> In the question of OPS two parties are always involved. You have the ship and the shore facility. Implementing OPS is expensive and when a port decides to invest in it, they need to have a guarantee of having enough vessels with OPS connections to have a viable business case (...) For Eni and Polarbase, this was not a concern. We will have activity offshore from this port for at least 30 years, and we know that our presence

here will increase. So, our vessels will traffic this port for at least 35–40 years from now (Eni, Electricity Consultant).

These quotes illustrate that knowledge and technology in the petroleum sector were important to OPS implementation. Furthermore, Eni S&P representatives argued that OPS depends on many actors, each of which has different interests and aims; for example, ship owners will invest in the ship-to-port connection only if sufficient ports offer OPS. As a result, whether OPS implementation is economically viable is also a question of strategic choices at different ports across the entire sector, beyond the region itself. Thus, in the region's petroleum industrial path, petroleum sector knowledge and technology were important for successful OPS implementation, which was also driven by institutional changes. Eni has been a key actor in this process by drawing on their extensive experiences and networks and illustrating the effects of purposive firm agency in stimulating the greening of regional industrial paths.

Discussion

In sum, compared with the maritime case discussed here, sectoral characteristics (knowledge and technology, actors, networks and institutions) influenced Eni's taking a more central role in funding OPS. The offshore sector's financial situation facilitated its role in taking a new step towards a greener alternative. The sector's role as a major polluter also helps explain this attempt to reduce its environmental impact. Finally, being a lead firm within a global industrial network, Eni S&P and the shipping companies can lead the way for other companies. This illustrates how, in the case of Eni's implementation of OPS, the institutional set-up of the petroleum industry, coupled with available technology, served as a driver for greening the regional petroleum path.

Hence, OPS has been implemented in the region's petroleum industry but not, to date, in its maritime industry. Empirical insights regarding different characteristics in the two sectors are important for understanding the barriers to, and potentials for, greening the investigated regional industrial development paths. We have demonstrated how explicitly considering sectoral characteristics in analyses of greening of regional industrial paths, e.g. how firms are supported by and linked with other actors and support mechanisms in their sector, can inform studies of regional industrial path development and greening. We investigated one technology, OPS, to illustrate how private and semi-private companies in the maritime and petroleum sectors of a single region have diversified beyond traditional methods for organising production and services. We also explored the differences and similarities in how firms reduce their adverse environmental footprints and impacts. Our qualitative analyses revealed the importance of sectoral characteristics in explaining why the region's maritime sector firms have struggled, while those in the petroleum sector have succeeded, in their efforts for greening the regional industrial path (Table 2). In addition, and consistent with SIS and recent EEG research, we have also illustrated the role of (firm) agency and multi-scalar dynamics in explaining how industries evolve in regions. This is particularly well exemplified by the role of Eni in implementing OPS.

Table 2. Summary of empirical findings

	OPS implementation status	**Explanation**	**Possible impact on greening of the region's established path**
Maritime sector	OPS implementation currently missing	Attempts to introduce OPS, but sectoral characteristics explain	Low

		why regional actors meet obstacles	
Petroleum sector	Successful OPS implementation	Beneficial interplay between territorial and sectoral characteristics; lead role taken by dominating firm	Medium

The region's maritime industry is motivated to reduce emissions from docked ships by supplying shore power. However, while the idea is innovative and can lead to both growth in existing local firms and new formation of specialised firms, challenges to developing a necessary infrastructure hamper OPS implementation in the harbour. In fact, the economic investments cannot be financed by the harbour itself, and maritime actors are awaiting signals at the governmental and policy levels. By contrast, the case of Eni S&P in the offshore supply sector has taught us that joint OPS collaboration between the local supply base and oil industry firms could fund the necessary infrastructure, which in turn, facilitated new ideas and markets for local energy companies. As pointed out by Malerba (2002), firm agencies are central to such contexts, by influencing adaptation to new technology. Oil industry firms took a strong, active role in funding OPS, while Tromsø port firms await policy systems to support, create incentives or contribute public funding to realise an OPS infrastructure. Thus, interplays between knowledge and technology, actors and networks, and institutions—characteristics of a sector—are important for explaining the observed outcomes.

Narrowing in on how industry companies act, and thus create and alter existing paths based on combined exogenous and endogenous factors, gives us insight to assess how actors produce specific, or even desired, effects. We can observe that actors located outside the region, including Rolls Royce Bergen and the Møkster company, produce technologies that reduce negative environmental impacts, and that the Italian oil company Eni S&P has

purposefully implemented this technology within the petroleum sector in the region (Nilsen, 2017).

However, the challenge in the maritime industry towards a green transformation is not merely about market transactions. Overall, based on its existing knowledge and technology, the maritime sector is a relatively heterogeneous group of firms that faces a range of challenges in developing new solutions and becoming "greener" (Steen et al., 2019). Their challenges differ in scope and scale, and they relate to incremental and disruptive improvements; these challenges are also related to the sourcing of new knowledge and infrastructural endowments both within and outside the existing firms' control. The SIS framework highlights how sector-specific institutions, or the "rules of the game", influence innovation and firm activity (Malerba, 2002). Markets, regulations and standards are important dimensions in this respect. In the present case study, we found that standards, or practices in procurement procedures and established practices within the maritime sector, represent one barrier to the greening of the existing path. Conservative procurement practices facilitate continued efforts to reduce uncertainty and economic risk. Today, incentives that could have facilitated new, green solutions to implementing new technology are largely missing. The challenge is that while companies in a region can be proactive regarding new technologies and possibilities, sectoral institutions regulating actors and customers within the value chain may hamper the development and implementation of greener solutions.

Both of our examples include changes that, if distributed broadly, will have influences beyond the company that implemented the technology. Such implementation may influence adjacent actors in the region, who will adapt to the new technological solution, which has the potential to stimulate suppliers and customers towards new market opportunities. This will challenge actors who hold a traditional view of technology and will have the long-term effect of reducing competitiveness among firms that are unable to adapt. In other words, it is

reasonable to assume that OPS implementation can contribute to greening of the region's existing industrial paths. Hence, if firm agency for restructuring towards more sustainable business models is low, we expect that its innovation character will also be either low or marginal; in that case, we also expect that its industry path will be path-dependent, making its greening difficult. Being unable to respond to exogenous sources of new industry path development, as in the Tromsø harbour example, illustrates this point. However, other endogenous factors, such as company representatives and internal policies within the maritime industries, also drive new and more sustainable business models and technologies. One interviewee stated that there is an ongoing change in the sector, that new individuals entering the sector are more concerned about the environment (interview data). Existing knowledge and technology, and how the industry has worked on emissions prior to the increased focus on green solutions, are also relevant to understanding this. The combination of these two drivers, both exogenous and endogenous factors, can be understood as activities that are performed by heterogenous actors and networks. This involves not only those developing new technologies and products, but also actors who provide complementary assets, innovation support structures and customers (Garud and Karnøe, 2003), but where the firms are on the "receiving end" of the changes.

When it comes to sources of greening within the maritime sector, we observed that a combination of exogenous factors beyond the northern region of Norway have led to the adaptation to new climate policies and CP21 (one example of institutional influence). Pressures from the exogenous policy environment and public opinion can be interpreted as a burden on industry sectors that are unable to adopt more sustainable and greener technologies. Another important dimension in the discussion of sectors' abilities to "exchange between" different available technologies is the question of resistance. Different systems of innovation (i.e. regional, sectoral, technological) may become available when it comes to embracing a

new technological system. As SIS research highlights, the role of knowledge and technology is central to understanding innovation capabilities. We observed that the oil industry firms could apply knowledge that reduced its threshold for adapting to the new technology needed to implement OPS. Though they were successful in using established technology, they also changed their technological trajectory in this specific case. Thus, success with established technology cannot entirely explain resistance to applying a new system.

Hence, sectoral differences between petroleum and maritime industries highlight our argument herein regarding the importance of considering both regional and sectoral characteristics when investigating greening of regional industrial development paths. As we have demonstrated here, the region's maritime sector firms have struggled to implement the green OPS technical solution, while those in the petroleum sector have succeeded. While they are operating in the same regional context, the respective firms have been particularly influenced by their sectoral belongings.

Concluding remarks

Herein we have argued that regional industrial path development must be considered interwoven on different spatial scales, rather than being confined to regional contexts. Our thinking on these issues has been influenced by discussions of actors and agency, and how actions or interventions by individuals or groups can influence regional green path development (Jolly et al., 2020). From firms' regional and sectoral perspectives, there are several obstacles to greener, more sustainable development (Aarstad and Jakobsen, 2020). This is related to both internal and external market competition, general market conditions and the need for short-term profits (Aslesen et al., 2017). Furthermore, our focus on firm agency acknowledges the heterogeneity of firms in regions and that "similar" firms can, in reality, differ markedly (Martin, 2010; Penrose, 2009). In addition to their embeddedness in regional dynamics, firms are strongly influenced by sectoral characteristics. However, the role

of sectoral characteristics has been downplayed in the regional industrial path development literature. After all, 'different industries have different innovation practices and […] regional capabilities are the sum of very diverse capabilities embedded in various actors within the region' (Moodysson and Zukauskaite, 2014: 136). Thus, we have called for a stronger focus on sectoral characteristics to explain regional industrial path development. To achieve this, we have used a theoretical approach to draw on SIS concepts. Taken together, SIS is a concept that, theoretically and empirically, informs the regional industrial path development literature and the increasingly popular topic of greening of regional industries. In its analytical orientation, SIS focuses on firms and how they are supported by and linked with other actors and support mechanisms (e.g. industry facilitation, R&D institutions) and, hence, differs from the EEG literature, which is mainly concerned with regional dynamics. Thus, SIS offers explanations for how sectoral characteristics can be approached, implicitly also contributing an understanding of the role of multi-scalar dynamics in explanations of industrial development (Binz and Truffer, 2017). Hence, the SIS concept has assisted us in further developing theoretical propositions and analytical approaches within the regional industrial path development literature towards better including differences between sectors and how sectoral characteristics can help explain greening patterns of regional industrial paths.

As illustrated by our empirical investigation, regional firms belonging to the maritime sector have struggled to implement the green OPS technical solution, whereas those in the petroleum sector have succeeded. Our analysis shows that while they are operating in the same regional context, the respective firms have been particularly influenced by their sectoral anchoring; this is important for explaining the difference in observable outcomes in green OPS technology implementation.

Further research should focus on the intersection between firms in different regional contexts. As greening initiatives have become increasingly prominent in both metropolitan

and rural regions, further studies should investigate not only how geographical contexts encourage the greening of industrial activities, but also how different sectors and region types may "come together" differently to influence the greening of regional industries (see also Binz and Truffer, 2017; Njøs et al., 2020). Further empirical, conceptual and theoretical work is needed to provide a better explanation of the nuanced interplays between regional contexts and different sectors. Additionally, and linked to recent interest in the regional industrial path development literature regarding agency, we believe the SIS concept and literature provide important analytical insights regarding the role of firms in regional industrial path development and how this topic can be further investigated based on spatial understandings.

The policy implication herein is that regional policy actors should note that a region's actors and sector compositions play different roles in the greening processes of regional industrial paths. Facilitating collaborations between regional policy and industry actors by establishing arenas for sharing intra-sector knowledge within a region can trigger new knowledge about important barriers, as well as potentials, in industrial path greening. In addition, we argue for greater sensitivity towards the role of regional policies in influencing greening processes in regional industries. As shown herein, policies and institutions at different spatial levels and linked to different sectors do indeed influence activities among firms in a regional industry. That regional policy actors must navigate complex policy milieus on different spatial levels encourages caution against overly optimistic understandings within the EEG literature about the role of regional policies in contributing to green industrial path development.

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