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ABSTRACT
This paper investigates the radicalness of industry path transformation in different geographical contexts by analysing the introduction of new technological trajectories within established industry paths. We use an analytical framework based on path dependence theory to conduct a comparative case study of the introduction of offshore farming technology in the salmon farming industry in both coastal Norway and Tasmania, Australia. We show that similar points of departure can lead to different path transformation radicalness. In each case, the transformation outcome will depend on the unique interplay between agency and regional structural components during windows of opportunity. The empirical analysis supports the importance of considering agency, regional structural components and global technology trends when investigating path transformation radicalness.

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KEYWORDS
innovation; salmon farming; path development; evolutionary economic geography; path transformation

1. INTRODUCTION

Industrial economic development does not unfold uniformly. According to the path dependence perspective in the Evolutionary Economic Geography (EEG) literature, new growth dynamics evolve out of existing structural conditions in regions (e.g., Martin, 2010). Place-based conditions and existing industrial activities shape industry paths' development over time (Neffke et al., 2011). Industry paths may also enter periods of transformation which involve technological innovation, which can be seen as the purposive behaviour of directed decision-making by territorially embedded economic agents (Garud & Karnoe, 2001; Martin & Sunley, 2006). This article focuses on the transformation of the salmon farming industry paths in two selected regions (coastal Norway and Tasmania, Australia), where path transformation is defined as 'innovation-based renewal processes of an established path based on radically new technological, organizational or market innovations' (Miörner & Trippl, 2019, p. 1246). Understanding this interconnectedness between the regional context and technology development in path transformation processes is crucial, and theoretical advancements with greater attention to agency and how incumbents and new entrants transform an industry have been made by Grillitsch and Sotarauta (2019), Miörner and Trippl (2019) and Njøs et al. (2020). This article builds on these lines of thought.

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Salmon farming is a primary industry with a dependence on industrial and technological capabilities as well as relevant environmental factors (natural resources) and enabling politics, making only a few places suitable for salmon production (MOWI ASA, 2022). Global solid demand (Food and Agriculture Organization (FAO), 2022) and strong positive path dependence (Aarset & Jakobsen, 2015) have resulted in the salmon farming industry becoming the most technologically advanced aquaculture industry in the world (FAO, 2022). Novel technological production methods such as offshore systems have been developed to expand viable production areas from the more traditional open-pen farming methods closer to shore (Fløysand & Jakobsen, 2017). This paper investigates two important salmon-producing regions: Tasmania, and coastal Norway, where aquaculture activity span from Troms og Finnmark county in the north to Rogaland County in the south. In both regions, we have observed the introduction of offshore farming as new technology trajectories within the existing industry path, but the outcomes differ. The analysis is based on an observation that path transformation processes are set in motion by political actors and authorities – in Norway through the introduction of the development licence regime (Fløysand & Jakobsen, 2017) and in Tasmania through policy authorities' introduction of new farming zone regulations (Fløysand et al., 2021). These triggering events create windows of opportunity, providing possibilities for introducing new technologies and the transformation of the salmon farming industry paths (Miörner & Trippl, 2019).

This paper uses the empirical insights from industrial path developments within the salmon sector in two different regions to investigate how the interplay between agency and structural components in regions decides the radicalness of technology transformation outcome (Boschma et al., 2017; Njøs et al., 2020). To analyse the outcome of these path developments, we investigate how the interplay between the agency of industry actors and structural components in the region leads to the transformation of the salmon farming industry. We draw on insights from the path development literature (e.g., Miörner & Trippl, 2019; Njøs et al., 2020; Steen, 2016) and identify various structural components for our analysis. Furthermore, our focus on the radicalness of path development outcomes provides a suitable empirical assessment of a recent contribution by Boschma et al. (2017), which provides a typology of the radicalness of industry path transformation. The following two research questions will be investigated:

- What are the similarities and differences in path transformation toward offshore farming within the salmon farming industries in coastal Norway and Tasmania?
- How does the agency of actors and structural components in regions explain the radicalness of path transformation during windows of opportunities?

In addressing these research questions, the article continues with a brief theoretical discussion followed by a presentation of the analytical framework in section 2 before describing methods and data in section 3. In section 4, we present the empirical analysis. Section 5 discusses the empirical observations by linking the findings to the analytical framework. Finally, section 6 concludes.

2. REGIONAL INDUSTRIAL DEVELOPMENT

Our point of departure is rooted in the path dependence theory, which describes the development of the economic landscape through the twin processes of continuation and change of industrial paths (Martin & Sunley, 2006). Our theoretical approach revolves around understanding the radicalness of industrial path transformations (Boschma et al., 2017) as contingent on triggering events that create a window of opportunity for agents to influence the trajectory of path development (Grillitsch & Sotarauta, 2019). Agents exploit structural components in regions when responding to windows of opportunity, but these components also restrict their action (e.g., Trippl et al., 2020). Thus, the path transformation outcome is a function of the interdependence and interplay between agents and structural components in regions. Figure 1 illustrates this process. The remainder of this section will detail our theoretical framework.

2.1. Triggering events and agency

Path dependence theory rests on the notion that spatial economic growth patterns emerge from processes that take place in the past (Frenken & Boschma, 2007) and mainly relies on *triggering events* that set path development in motion (Mahoney, 2000). While the early conceptualizations relied on the influence of external triggering events, new work on path development highlights the agency's role in such triggering events (e.g., Isaksen et al., 2019). There is a general agreement on the need for a disruption or a triggering event for path development and path transformation to be initiated (Simmie, 2012), providing an escape from path dependence 'lock-in' (Martin, 2010).

Agency, defined as 'action or intervention by an actor to produce a particular' effect (Emirbayer & Mische, 1998; Sotarauta & Suvinen, 2018), has been particularly helpful in understanding breaks in path dependence. Scholars such as Simmie (2012) argue for overcoming path dependence lock-in by mindful deviation by knowledgeable agents inspired by work performed by Garud and Karnoe (2001). A later seminal article by Garud and Karnøe (2003) found that agency spread out over a plurality of agents in innovation processes may lead to the development of more radical technology by combining unrelated knowledge bases. This line of thought has inspired more work on the role of agency and brought attention to the need for both firm-level experimentations and system-level building activities in more radical path transformation processes (Boschma et al., 2017). In this paper, we find the distinction between *system-* and *firm-level* agency proposed by Isaksen et al. (2019) enlightening for understanding industrial restructuring.

Renewal and innovation rely not only on the internal competence of firms but also on networks and systemic configurations that stimulate cooperation. System-level agency transcends organizational borders and can mobilize other actors, guiding the behaviour and influencing organizational strategies toward path transformation (Isaksen et al., 2019). Examples include lobbying, promoting activities, attracting funding, knowledge creation in universities, cluster

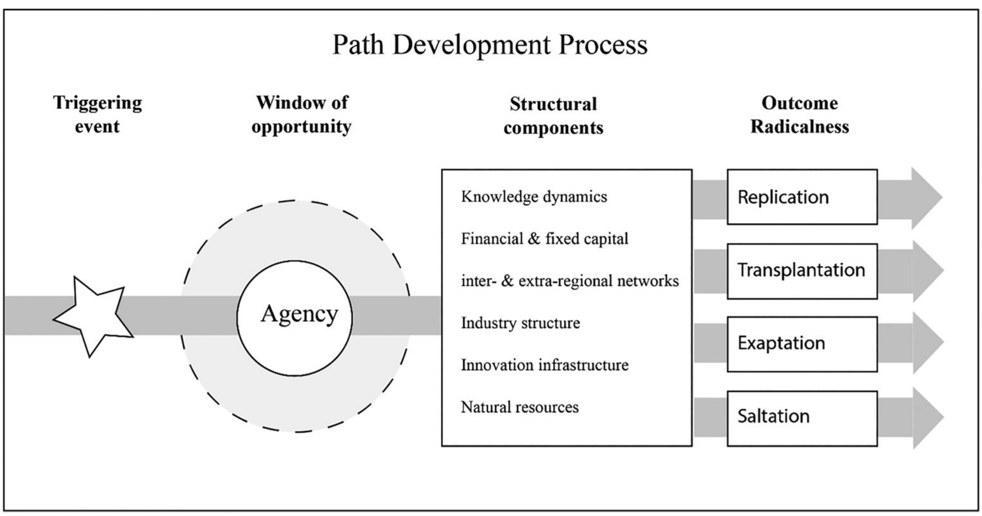

Figure 1. Analytical framework.

programmes, policy support initiatives, and national and regional policy programmes (Trippl et al., 2020). Especially policy may play a key role in path development, where policy mixes can be designed to facilitate a transformation (Tödtling & Trippl, 2018). Studies have examined how firm and non-firm agents, including state actors and public policy, deliberately create favourable regional environments for path transformation (Dawley, 2014) orchestrating fundamental mechanisms of path development through contextual policy interventions (Dawley et al., 2015). We thus view the agency of policy actors as able to create a window of opportunity in a particular industry, reinforced by recent empirical investigations by Jakobsen et al. (2021).

However, new path development also requires industry actors who initiate new firms or innovation activities in existing firms. A firm-level perspective considers the impact of agency on industrial transformation on how actors introduce innovations, experiment with new technology, adapt existing technology (Trippl et al., 2020), or start new innovative ventures or organizations (Isaksen et al., 2019). These entrepreneurial activities are motivated by profit opportunities, and new ideas, inventions, or innovations are developed based on regional opportunities. While new entrants are often seen as the main engine for radical innovation, considerable evidence suggests that established firms actively pursue novel technological trajectories to diversify their assets due to altered selection pressures (Steen & Weaver, 2017). In capital- and resource-intensive industries such as salmon farming, the agency of incumbents may be of particular importance.

2.2. Structural components in regions

As regional industrial path development does not unfold uniformly across the globe, defining the specific regional structural components that influence different outcomes is necessary. From our analysis of the path dependence literature (e.g., Binz et al., 2016; MacKinnon et al., 2019; Njøs et al., 2020; Steen & Hansen, 2018), as well as the discussion above on the importance of distributed agency, it is clear that both well-known innovation drivers such as knowledge, finance and networks are essential. Still, the surrounding configuration of the surrounding regional structure should also be considered. This section details the structural components that, according to path dependence theory and related literature, influence technology transformation in regions: (1) cumulative and combinatorial knowledge dynamics, (2) financial and fixed capital, (3) intra- and extra-regional networks, (4) specialized or diversified industry structure, (5) thick and thin innovation infrastructure and (6) natural resources.

The role of knowledge has been central in path dependence theory as a factor explaining the innovative capability of an industry (Martin, 2010). The production of breakthrough innovation requires agents with the ability to recombine different types of knowledge (Castaldi et al., 2015). Following Strambach and Clement (2012), we use the distinction of cumulative and combinatorial *knowledge dynamics* to further expand on the processes forming breakthrough or incremental innovation. Cumulative knowledge dynamics means the generation of new knowledge builds on existing and current knowledge. The firms' capability to absorb new knowledge and the direction of new knowledge depends on previous development (Cohen & Levinthal, 1990). As knowledge emerging through cumulative processes is reinforced and stabilized by institutions over time, cumulative knowledge is characterized by a high degree of relatedness in the form of technological innovation, technology with similar characteristics, and a high degree of certainty of the outcome (Strambach & Klement, 2012). Combinatorial knowledge, on the other hand, requires successful transformation, recombination, or creation of institutions as many different cognitive, technological, organizational, and institutional interfaces need to align (Strambach & Pflitsch, 2018). A high degree of cognitive diversity and a low degree of shared knowledge leads to the generation of combinatorial knowledge, which needs the unification of initially separate knowledge bases that may be spread over a variety of actors that are often located in a different technological or regional context. On the other hand, combinatorial knowledge is characterized by more uncertainty due to the unrelatedness of knowledge bases as the process may require restructuring of value chains leading to increased distance cognitive distance.

While path dependence theory traditionally has focused on knowledge-centric explanations of path development, scholars such as Binz et al. (2016) argue that financial investments are a critical structural component for industry formation. *Financial capital* is often a scarce resource for actors in a new industrial field and may need to be mobilized from various sources, both within and outside the region, ranging from risk-taking angel investors and venture capital to more risk-averse investment and commercial banks (Florida & Smith, 1993). The uncertainty and risk lead to the need to form stable alliances with investors and intermediary actors to secure continued investments. Funds may also be raised from governmental organizations or intermediaries to fund research and development (R&D) and demonstration projects (Hekkert et al., 2007). *Fixed capital*, on the other hand, is the value of capital resources available for production purposes, such as factories, machinery, vehicles, and other physical assets. These resources are less 'footloose' than financial capital and are embedded into the region. In path development, new technologies start as generic assets and evolve into specific ones. Fixed capital is thus often tied to the physical manifestation of technology in a particular region, leading to path dependence and 'lock-in' though sunk cost into technology-specific infrastructure (Martin & Sunley, 2006).

The *intra- and extra-regional networks* of firms and non-firms (i.e., cluster organizations, research organizations, NGOs, and governmental institutions) enable the flow of ideas, practice and knowledge (Njøs et al., 2020). Empirical findings from Strambach and Clement (2012) show that innovating actors establish loosely coupled networks that decrease that facilitate knowledge combination. However, intra-regional networks and geographical proximity is insufficient for knowledge creation and sharing, particularly for combinatorial knowledge dynamics. Extra-regional networks link to other regions where similar technological developments occur (Binz & Truffer, 2017). Through these networks, firms may access extra-regional knowledge such as the technological state of the art and advanced research milieus. Establishing new networks is thus a crucial process, especially for absorbing unrelated knowledge, which may be extra-regional. Competence and resources may be developed in related actor networks outside the region and embedded in the regional path development process through collaboration and networking between local firms, multinational corporations, or other multi-spatial organizations (Binz et al., 2016).

The *industry structure* within a region will affect possible knowledge and technology transfers to the industry in focus and is affected by knowledge and technology relatedness. Firms extend activities to knowledge-related technological fields (Breschi et al., 2003) and skill-relatedness (Neffke & Henning, 2013). This process leads to the agglomeration of technologically related industries, for example, supplier linkages and a pool of skilled labour force. New industries emerge in regions with a technological relation to pre-existing industries, and this technological cohesion persists over time despite structural change (Neffke et al., 2011). However, a regional industry mix consisting only of related industries may lead to lock-in and regional decline, which fails to account for how more radical forms of novelty are introduced in industries in a region. Thus, attention has shifted toward unrelated industry diversification: 'the more radical the transformation in the underlying local capabilities is needed to develop a new activity, the more it concerns unrelated diversification' (Boschma, 2017, p. 355). Industries are also embedded in region-specific contexts and depend on the underlying regional capabilities. On the one hand, regions may be diversified and facilitate unrelated diversification in regional industries. On the other hand, regions lacking the capabilities required for new activity constrain industries toward related diversification.

To capture such variance in regional industry structure, we can make a simplified distinction between a specialized and a diversified industry structure (Deegan et al., 2022). A *specialized industry structure* is dominated by a few industries with supportive innovation infrastructure tailored to the region's industrial base. While this industry structure often has a high degree of alignment with the other structural components, leading to fewer barriers to path development, the relatedness between firms may lead to groupthink and lead to lock-in, preventing path transformation (Grabher, 1993). On the other hand, a more *diversified industry structure* is characterized by more heterogeneity, with multiple coexisting industry paths and a more varied supportive innovation infrastructure. This industrial structure has less alignment with regional structural components, leading to opportunities for path transformation due to the opportunity to collaborate with unrelated industries, at the risk of lacking support and fragmented initiatives (Deegan et al., 2022).

The *innovation infrastructure* comprises public support systems, research and educational institutions, and various interest organizations that firms use in their innovative activities. Increasingly attention has also been given to other intermediary non-firm actors engaged in the innovation processes (Sotarauta et al., 2021). Such actors may include cluster organizations, trade organizations, non-governmental organizations (NGOs), funding bodies and consultants, which support firms through agency at the system-level, which may both enable (Grillitsch & Sotarauta, 2019) and hinder (Bækkelund, 2021) path development. These strategic actors intermediate between multiple other actors, organizing discourse and creating conditions for learning in innovation systems and can reorganize, change, and renew system structures and contribute to changes in policy instruments (Isaksen et al., 2019). To capture the importance of these knowledge-producing non-firm actors, we draw on the concept of thickness, seen as the number, quality, and variety of organizations located in the region. A thick innovation infrastructure facilitates strong knowledge circulation, intraregional networks, and system change. In contrast, a thin innovation infrastructure facilitates system continuity and requires actors to source knowledge from outside the region (Isaksen & Trippl, 2017).

Finally, there are strong reasons to consider *natural resources* in path development, as it has been described as an essential component in the path development literature (e.g., Kyllingstad et al., 2021; MacKinnon et al., 2019; Trippl et al., 2020). Natural resources have a heterogeneous distribution, such as a coastline or other natural environmental features that enable or constrain specific industries. Primary industries, such as salmon farming, rely on natural resources such as physical production localities with specific environmental conditions needed for fish rearing. As industries expand or the conditions of the natural environment change over time, the scarcity of suitable production localities may stimulate the need for path transformation (Hansen & Coenen, 2015). Technological developments may enable such developments, for example, successfully exploiting previously inaccessible production localities or encouraged by environmental degradation and social resistance (Fløysand et al., 2021).

2.3. Path transformation outcomes

The interplay between agency and structural component configurations described in the previous chapters lead to industrial and technological change processes that may be incremental or disruptive to the current industry (Boschma et al., 2017). Following the path development literature, incremental change is seen as more connected to relying on existing structural components in the region (Frenken & Boschma, 2007), while recombining previously unconnected technologies may lead to radical change in capabilities (Castaldi et al., 2015). Thus, the industrial path development process is also contingent on extra-regional industrial components, that is, the technological state of the aquaculture industry developed elsewhere (Binz et al., 2016).

These components can become available to the regional industry by forming extra-regional networks by actors through connections such as international collaborations and joint ventures (Binz & Truffer, 2017). Also, as more radical outcomes need more extensive system changes to break from regional and sectorial factors, the more radical the outcome, the more system-level agency is required (Isaksen & Jakobsen, 2017). We view path transformation as an outcome that should be linked to the region's existing industrial trajectories and to the more general technology trend within a global industry, that is, 'state of the art' (Murmann & Frenken, 2006).

In sum, we present an analytical framework where we view path development outcome as more or less radical, depending on how much the new industry trajectory diverges from existing regional industry trajectories and to which extent it is similar or diverges from the more general technology trend within a global industry. We link these assumptions to the four stylized transformation trajectories presented in Boschma et al. (2017).

Replication is the least radical path transformation, and it points towards a development trajectory incrementally different from the existing regional industry path and the technological state of art of the sector. This outcome can be associated with a specialized industry structure, limited fixed capital and a thin innovation infrastructure that may require support from interregional networks. It also necessitates firm level agency to exploit existing regional natural resources though technology built on cumulative knowledge creation. This trajectory can be expected in peripheral 'left-behind' regions without globally competitive industries.

Transplantation is a more radical outcome than replication. It is characterized by importation of a technological trajectory from the global industry to the region. The new trajectory is radically different from existing regional industry path but incrementally different from the technological state of the sector. A specialized industry structure supported by a thick innovation infrastructure, fixed capital, and interregional networks may support the implementation of this trajectory. There is also need for combined system-level agency and firm level agency to enable the utilization of existing local resources in a new way.

Exaptation is an outcome that is even more radical than transplantation. Exaptation is an outcome than is radically different from the technological state of the industry, but that still build on existing technological competence within the regional industry. A diversified industry structure supported by an innovation infrastructure, financial capital and intra-regional networks may promote this development. There is also need for a combinatorial knowledge creation driven by firm-level agency, enabling more efficient utilization of existing resources. Collaboration between R&D institutions and regional industry actors creating globally competitive technology can be an example of exaptation.

Saltation is the most radical transformation of the industrial path. This outcome is radically different both from the existing technological trajectory of a regional industry as well as the technological state of the sector. A diversified industry structure supported by a thick innovation infrastructure, financial capital, and intra- and interregional networks may promote this trajectory. The innovation process may also be characterized by combinatorial knowledge creation driven by firm- and system-level agencies and the utilization of resources previously inaccessible. The trajectory can be exemplified by a cutting-edge global oriented industry in a region building competitive advantage by heavy investment in R&D and using new collaboration possibilities with adjunct industries.

The analytical framework (Figure 1) is used to investigate path transformation through the transformation from open-pen salmon farming in the coastal area toward offshore salmon farming in two salmon production areas. The framework informs the empirical investigation by lending a theoretical lens on how path transformation outcomes depend on the unique interplay between agency and regional structural components and global technology trends during windows of opportunity.

3. METHOD AND DATA COLLECTION

This paper is based on empirical observations from the regional innovation complex surrounding offshore aquaculture in two salmon-producing areas, coastal Norway[1] and Tasmania.[2] We conduct an in-depth investigation of path transformation by deploying a case study methodology. We follow a comparative holistic two-case-study design with contrasting empirical situations offering useful conditions for theoretical replication, strengthening the generalizability of our findings (Yin, 2009).

The areas were chosen since, at the time of the data collection, coastal Norway and Tasmania were the only two salmon-producing areas with developments toward offshore salmon farming. A qualitative comparative case study combining a descriptive and comparative research design was conducted in Tasmania and Norway in early 2020, with supplementing data-gathering continuing throughout the year. First, we started to list key salmon aquaculture stakeholders in Tasmania and Norway from informants well connected in both areas and supplemented the list through 'snowball' sampling during the fieldwork. The face-to-face interviews consisted of 24 stakeholders in Tasmania and eight in Norway during the fieldwork. After supplementing with digital interviews (one in Tasmania and four in Norway), the final numbers ended at 25 and 12. Four stakeholders declined, 10 did not answer and two interviews were cancelled.

Ultimately, the primary data consisted of 17 interviewees in the industry (salmon companies, suppliers and their business organizations), of which 11 represented coastal Norway while six represented Tasmania. Out of 10 interviewees representing public authorities, one represented coastal Norway while nine represented Tasmania. Five interviewees represented research institutions, all of which represented Tasmania. Four interviewees represented non-firms: one represented coastal Norway, while three represented Tasmania. Our primary data thus consist of 37 stakeholders in 24 individuals – and five group interviews of 30–90 minutes. The interviews covered the industry and its technological development and innovation activities, social and environmental pressures, policy, regulations, and current and future challenges. Secondary data were collected from strategy documents, technical reports, governmental industry guides and documents from the development licence archive on the Norwegian fisheries directorate to supplement the data set. The data collection continued until saturation of information could be observed. The primary interview data were processed, transcribed, triangulated with the secondary data and structured in an analysis highlighting the emergence of offshore salmon farming based on triggering events. From the interviews, we collated information on what we deem events of particular importance – identifying critical decisions and events that have led to a specific outcome.

4. EMPIRICAL ANALYSIS

4.1. Salmon farming in coastal Norway: characteristics of the industry

Coastal Norway is the dominant salmon-producing country within the industry where modern salmon farming practices originated. The Norwegian seafood complex comprises interest organizations, salmon farmers, technology suppliers, fishing vessels, start-up accelerators and incubators, investors, supporting firms, research institutions, investors, and an advanced regulatory framework. Most of these entities are present in the Bergen region in Norway, which is considered the global capital of aquaculture (Lindfors & Jakobsen, 2022). Four out of five of the world's largest salmon producers (MOWI, Lerøy, Cermaq and Salmar), as well as many small and medium-sized companies (120 licence-holding firms in total), have the majority of their activity in coastal Norway, and the sector employs some 22,000 people directly or indirectly (MOWI ASA, 2022).

The seafood sector in coastal Norway is characterized by having a high R&D intensity with strong public R&D institutions receiving significant funding and an industry that can rely on an extensive innovation system (Fløysand & Jakobsen, 2017). The strong industry incumbents in Norwegian salmon farming have enjoyed a considerable accumulation of resources due to a high salmon price in recent years and a 1.45 million Tn production, valued at €6.8 billion in 2019 (Statistics Norway, 2020). 'In Norway, we have had very competent farmers and have achieved a collaboration between research, government, and industry, laying the foundation for growth and development. However, this development has only materialized in salmon farming … ' (government representative 1).

As the industry has matured, the scientific capabilities of the firms have increased, and the experimental trial and error knowledge has increasingly been supplemented by scientific knowledge. The Norwegian national cluster strategy has also been important for the industry to facilitate the creation of regional structural components such as networks, knowledge production and specialized infrastructure. The industry has had a sizeable cross-political unity on the broad strokes in industrial governance that have created a stable foundation and provided a long planning horizon for industry actors. Similarly, an advanced regulatory system has been developed to ensure the sector's sustainable development. The regulatory system's focus on sustainability has resulted in considerable growth restrictions for the industry. In coastal Norway, a salmon farming licence awarded by governmental institutions is needed to farm salmon for each locality or facility established on land or at sea. Sea water licences are limited, and 1051 such licences were awarded as of 2019 (Directorate of Fisheries, 2020).

4.1.1. *Triggering event – development licences*

One of the driving forces for developing new farming technology has been the Norwegian state of fisheries and the policy that new licences were to be earned by applying through development licences, where significant innovation and technological expertise were needed to secure a licence. So far, 20 development licences have been granted, and 82 denied (many are in an appeal process). The applications closed in 2017 and garnered 104 innovative new concepts classified as closed, semi-closed, or exposed depending on the degree of separation from the surrounding environment. Seven grantees can be classified as projects destined for exposed localities, according to Tveterås et al. (2020), understood as concepts based on offshore technology within this paper. Reasons for the choice to develop technology that could withstand more exposed conditions included restrictions imposed on growth by stringent regulations and a need for new areas firms have moved further into exposed areas. 'Salmar's Ocean farm1, Havmerden, Norway royal salmon's concept, Fjordlaks and all of them, its exposed concepts' (industry representative 1).

The development licence regime enabled but also required entrepreneurial experimentation within the industry, which industry experts consider a triggering event for the offshore industry in coastal Norway. While the policy regime required considerable investment and innovation for projects covering technological and scientific gaps within the industry, a 'carrot' was also implemented to enable firms to convert licences into ordinary licences after the completion of the project. To ensure diffusion of the learnings, every accepted project needed to provide a final report on completion to share knowledge with the broader industry (Moe Føre et al., 2022). Due to the high value of a farming incense, this provided a reasonable safety measure that would reimburse even failed attempts to the firms and further encouraged experimentation with risky technology.

> Ocean farm One … would probably not have been built without the development licenses. … What is good with the licenses is that, if we would not be successful, we could still convert them so that we got something back for everything we put into this. (industry representative 2)

To use more exposed conditions, the firms had to develop technology that was developed together with universities and partners outside the traditional salmon farming sector. One firm adapted technology used in the oil and gas industry and influences from the maritime sector. Technology infusion from the maritime sector resulted in developing mobile ship-like farms that could overcome regulatory and environmental challenges.

> [We use] the same kind of technology that they use in the oil rigs, in structure. But this one is adapted to salmon farming and not to pump up oil. But you can say that the technology is the same. (industry representative 2)

4.1.2. *Path transformation*

Coastal Norway has, since the triggering event toward offshore farming, increasingly positioned itself as a sustainable ocean production steward. The nation is currently leading a high-level ocean panel that argues for ocean protection and sustainable ocean production, resulting in a high degree of political unity and directionality in areas such as aquaculture.

> though the international engagements the prime minister have for the ocean for example, that it is possible to combine commercial production and preserve the ocean, so not only protection but also sustainable use. (government representative 1)

As aquaculture is a politically important industry, many informants are looking for the government to stimulate sustainable growth and create an environment that will enable investments and technology development. The offshore aquaculture path may be seen in politics as a sustainable transition from oil and gas (O&G):

> the prime minister picks up offshore aquaculture as a component … she is also clearer when the oil prices fell to the ground some years ago and pulled up offshore aquaculture in terms of thinking about transitions. (government representative 1)

In a recent report on the potential of offshore aquaculture in Norway, Tveterås et al. (2020) propose changes to the aquaculture regulations to better account for offshore farming and draws on regulations established in the O&G sector. Some projects are considered 'fast-track,' with tailored exceptions not to hinder development. Since the offshore farming projects have released their final reports and new scientific reports are being published, initial scepticism against offshore farming within the industry has changed as legitimacy has increased, and more firms are interested in pursuing offshore farming. Close collaboration and co-creational forces between governmental, scientific, and industrial actors have legitimized offshore farming as a viable industry path.

> Indirectly, they have said that they believe in this … [and] have started coordination work, oil, and energy department, oil directory to find areas offshore … [and] are serious with what they are saying, and that gives us a security that thing will fall in place. (industry representative 2)

Interviews with industrial actors highlight the importance of the recent stable industry-wide profitability to undertake significant investments into innovative projects such as offshore farming. Firms have started to tailor their value chains to the offshore farms to order well-boats that can handle rougher seas and have higher capacity, and suppliers are increasingly offering feed barges that can handle more challenging conditions. Offshore farming will require extensive adaptations of the value chain from suppliers and third-party firms to adapt solutions to handle the new requirements. Aquaculture suppliers do not have the internal capabilities to supply offshore farming, and many external suppliers from maritime and offshore sectors have been brought in. 'To operate a farm unit like this, you need special competence … if we had taken away the team and taken in a team from traditional farming overnight, then that would probably have failed' (industry representative 2).

The domestic capabilities to produce offshore infrastructure seem to have increased as Industrial actors in Norway are considering production in local wharves with the possibility of building offshore structures. Keeping the value chain local is preferable to many firms due to the Norwegian maritime industry's world-leading expertise and cost competitiveness.

As the Norwegian salmon farming industry contains several industry clusters, some have started to facilitate the shift toward salmon farming for oil and gas suppliers, partly due to the oil price fall in 2014. As the offshore farming path has become more established, strengthening network activities specific to offshore farming is getting increasingly important for the industry to lobbying efforts to enable further technological developments and increase the knowledge diffusion with new network organizations being created within Seafood Norway to work toward offshore farming. The entrance of suppliers with related maritime and subsea technological knowledge has resulted in the infusion of new technology and competence in the sector: 'We were very negatively affected by the last oil price fall, … We have many heavy and strong technology environments … especially oil and gas, maritime but also IT and other industries that increasingly are looking to aquaculture' (intermediary organization representative 1).

Collaborations between firms and research institutions have resulted in one firm sponsoring a professorship at the Norges teknisk-naturvitenskapelige universitet (NTNU) to develop new offshore technology when the capabilities are not in place within the firm. A new research centre focuses on technological innovation and participants and access to extensive research infrastructure such as hydrodynamic laboratories, vessel motion monitoring, simulation tools, and full-scale industrial fish farms, which have increased the offshore farming regional capabilities. The potential of exposed fish farming has received attention from several countries, including Scotland, the Faroe Islands, Chile, Australia, China, South Korea and Japan. Norwegian industry actors also see the possibility of locating offshore salmon farms closer to the international markets to lower carbon emissions of air freight and compete with land-based developments.

4.2. Salmon farming in Tasmania

4.2.1. *Characteristics of the industry*

The Tasmanian salmon farming industry is characterized by a few prominent firms and powerful research institutions, such as the Commonwealth Scientific and Industrial Research Organization (CSIRO) and the University of Tasmania (UoT). They provide solid international ties and networks with a robust scientific knowledge infrastructure. Compared with other salmon farming regions, the Tasmanian salmon farming industry is characterized by its modest yearly production of approximately 64,000 Tn of farmed salmon worth approximately €550 million in 2018 (ABARES, 2020). The industry has seen a sizeable yearly production growth where the domestic Australian market swallows most of the Tasmanian production. At the same time, a minor percentage is exported at a higher price to Asian markets.

The salmon farming industry in Tasmania has historical ties to Norway as the industry was set up in collaboration with the help of Norwegian actors' investments and expertise in the 1980s. These actors have since left as the industry faced turbulence. A consolidation process resulted in three significant firms remaining at the time of data collection (2020): Huon Aquaculture, Tassal and Petuna. While comparatively small, the industry is nonetheless important locally and generates significant revenues for the local state, and provides essential jobs:

> [we have] nearly 800 people employed …, 75% of our staff have a regional postcode … we are a $1 billion industry to this state that is massive to the state … bigger than the beef and dairy industries, put together. (industry representative 3)

Social friction has led to the firms taking a careful and scientific approach when communicating with the public on expanding their production capacity to reduce civic society anxiety. Both coastal Norway and Tasmania are regions with considerable ecological tourism, which has formed environmental solid protection groups, influencing the public policy climate in Tasmania. Thus, while the demand side provides few barriers to industry growth, the increasing challenges with environmental pressures from warming waters, eutrophication by increased biomass and social pressures, and limited available areas suitable for farming have guided salmon farmers into considering novel production methods (Fløysand et al., 2021).

4.2.2. *Triggering event – marine farming zone transfer*

A common sentiment among the informants in Tasmania was the importance of the events in the marine farming zone (MFZ) Macquarie Harbor. An expansion of the production capacity in 2012 from 8000 to 29,500 metric tons per year led to a situation that negatively affected the environment in the complex and unique Macquarie Bay, where the MFZ is located. The expansion led to a situation where the public had a much more critical outlook on the salmon farming industry, environmental monitoring improved, and the need to find new viable sites in areas with less risk of environmental burden.

> Macquarie Harbor, a few years ago, had that led to an inferior image of the industry. … And then there was an awful feeling generated around the … four corners … expose, … that was bad for the industry, a real turning point for the industry … . (research institute representative 2)

As options for growing their production in the production zones around Tasmania were severely limited, the actors had a range of choices on how to proceed to expand their production within the current legislative constraints. Huon Aquaculture invested considerable resources into developing the technology needed to handle the rough conditions demanded by more energy-intensive farming locations. In 2014, Huon Aquaculture developed offshore farming technology to move farms from shallow inshore sites to sites with good water flow and enough distancing to reduce disease transfer at high-energy sites in Storm Bay in southern Tasmania. The company has invested more than €65 million in their patented fortress net pens that build on incremental innovation on traditional pens that need to keep predators out and handle higher energy sites. As the fish also must withstand the high-energy sites, they are farmed for a longer duration on land to reach a larger size. 'This incident in Storm Bay, was it last year, 2018 it was on the front cover of the Mercury for … a whole week. Everyone was talking about, …, salmon farm escapees' (research institute representative 2).

To handle the environmental and social backlash from the public, the local government has modified aquaculture regulations to incorporate a system with demerit points and credits toward new leases to incentivize the possibility of switching to areas better able to handle the environmental externalities of salmon farming. '[T]he companies can be issued infringement notices … if you approve more than turn into demerit points, you can no longer hold the lease. So, there are very strong incentives for companies to do the right thing' (governmental representative 2).

There are still uncertainties in the industry about how much biomass the firms are allowed to farm in the MFZ Storm Bay. The authorities will set an upper limit for salmon farming production and plan to distribute licences among the participating firms. As of early 2020, only a tiny fraction of the storm bay localities was in production, but it is estimated that 30,000 metric tons of Atlantic salmon can be farmed in Storm Bay. Huon Aquaculture is aligning its activities to compete for a significant portion of the licences due to its offshore focus, arguing for economic incentives to invest in sustainable growth.

> We took a loss last financial year. … We have just come out of a five-year period in which we have invested. The company's invested the best part of 400 million in all of these things in enabling us to go offshore, to expand … we are ready to go for the next few years. (industry representative 3)

4.2.3. *Path transformation in Tasmania*

Proactive regional actors in firms and non-firms, such as environmental organizations, have pushed salmon farming to be moved into offshore zones due to social and environmental pressures. Firms have started to invest in adapting existing infrastructure to handle exposed waters better.

Due to the lack of innovation infrastructure and other industries, knowledge has been acquired from extra-regional sources. A large blue economy Cooperative Research Centre (CRC) research project with solid international ties to, for example, Norwegian offshore research projects, has been set up. The project has ambitions outside offshore salmon farming and focuses on cross-industrial collaboration. Linkages to somewhat unrelated industries that can use similar areas, such as renewable energy, have been formalized. The original plan of using maritime infrastructure was discarded, but the establishment of knowledge exchange is considered necessary.

> The aquaculture guys are the guys pushing for the platform, the renewable energy guys. There is a piggy-back … you do not need to be offshore in Australia for renewable energy, but it is a way of making the footprint more sustainable and cost-effective. (research institute representative 3)

The major regional producer, Huon, has long had a strategy to move a significant portion of its growth into an offshore production cycle that requires specialized equipment and considerable infrastructure investments. Their technology is, however, incrementally different than their current open pen technology. Thus, quite simple construction has been developed compared with the megastructures of steel that emerged in Norway's salmon offshore industry.

Advocacy due to social pressure has become particularly strong in the Tasmanian salmon farming industry following the window of opportunity. The Tasmanian Salmon Growers Association (TSGA) has shifted focus from a more scientific coordinating role to more public-facing lobbying activities showing directionality toward more sustainable practices (Environment Tasmania, 2020). By moving pens into more exposed locations, the waters are colder and more oxygen-rich while at the same time lowering the disease spread and eutrophication potential of the farms. As the industry is aiming to grow its production, while the allocation of areal is very much dependent on social and environmental factors, this new research project has brought on board a substantial and widespread constellation of partners to investigate the potential for offshore farming: 'everyone who does research in Tasmania. … We are trying to work with them to put in projects related to offshore farming, … disease surveillance, biosecurity … nutrition, physiology' (research institute representative 2).

Following the developments in the broader global salmon farming industry, the actors can gain essential operational knowledge that may hinder potential mishaps. CSIRO sees possibilities to learn from mishaps in the pioneering work done in Norway.

> as we really start to firm up where we need to look to get advice on issues we had not thought about or to see what people have already done … even dealing with the kinds of incidents you have had where you had to be the pen to flip over, so how do you deal with those situations or the escapees? (research institute representative 3)

5. DISCUSSION

Our empirical observations from coastal Norway and Tasmania make it clear that technological trajectories toward offshore farming are being developed. It is apparent that both industries are pursuing a relocation of salmon farming toward more exposed areas. Still, there is a marked difference in the way offshore farming technology has emerged in the two cases. The findings have been summarized in Table 1.

In coastal Norway, the proactive system-level agency by government actors was crucial to creating a window of opportunity that enabled the technological development of offshore farming. The requirements and opportunities of the policy regime fuelled entrepreneurial experimentation, further strengthened by accumulated fixed and financial capital crucial to providing innovative capabilities in recent years. The industry is supported by a robust innovation infrastructure such as research, educational, governmental, and interest organizations. The adjacent O&G and the maritime industries have innovation infrastructures, which have been integrated into salmon farming through intra- and interregional networks by firm actors and non-firm interest organizations. These networks provide a thick innovation infrastructure and a diversified industry structure incorporating the skills, knowledge, and experience accumulated in O&G and maritime enabling combinatorial knowledge dynamics. The new technological trajectory has enabled the utilization of natural resources in the form of offshore production areas that were previously inaccessible to the global industry and moved the global technological state of the art forward. Finally, we characterize the industry development in coastal Norway as a

Table 1. Comparative analysis of path transformation toward offshore farming in both coastal Norway and Tasmania.

Triggering event	Actors and agency	Structural components	Path development outcome
Development licence regime in coastal Norway	Creation of a window of opportunity through systemic agency by governmental actors through development licences. Creation of radical novel technological trajectories through firm-agency	Diversified industry structure consisting of multiple adjacent industries with inter- and intra-regional networks. Combinatorial knowledge dynamics with financial capital enabled through a thick innovation infrastructure leading to significant new natural resource utilization	Saltation offshore farming path transformation trajectory radically new to the region and to the global technological state of art
Farming zone regime in Tasmania	Creation of a window of opportunity by systemic agency of governmental actors. Mimicking of resources existent in the global regime by firm-agency to align with environmental and social concerns	Specialized industry structure consisting of a few actors with an intra-regional network, toward global industry. Cumulative knowledge creation with fixed capital bound by a thin innovation infrastructure leading to new natural resource utilization	Transplantation offshore farming path transformation trajectory radically new to the region, and incrementally new to the global technological state of art

saltation transformation (Table 1). The offshore farming technological trajectory is radically divergent from the existing industry in the region as well as the global technological state of art.

In Tasmania, proactive system-level agency by government actors was similarly crucial to creating a window of opportunity for technological development of offshore farming. However, the credit/demerit system was designed to mitigate the environmental and social impact by stimulating the transfer toward exploitation of a production zone in more exposed conditions. While the Tasmanian industry has engaged in entrepreneurial experimentation toward offshore salmon farming technologies, only a few firms exist, the industrial production is modest, and financial resources have been limited. The specialized industry system is dominated by salmon farming, with few interactions with other industries, supported by a thin innovation infrastructure. Thus, importing technology through extra-regional linkages through strong international suppliers and scientific institutions has characterized the technological trajectory, enabling more efficient exploitation of natural resources in the region. The technological trajectory diverges clearly from the regional industry path but is similar to some of the technologies that are the state of the art of the global salmon farming industry. The cumulative knowledge creation by importing related knowledge from the global salmon industry combined with incremental innovation in the region has resulted in a path transformation that can be characterized as *transplantation*, that is, a technology *traject*ory radically new to the region, but incrementally new to the global technological state of art (Table 1).

Overall, our analytical framework has successfully explained how trigger events lead to windows of opportunity for agency to create trajectories toward path transformation. We argue that the six structural components described in the theory section in combination with agency explain industrial and technological change processes that lead to path transformation trajectories. By linking path development outcomes to a typology inspired by Boschma et al. (2017), our analytical framework has been fruitful in comparing the radicalness of path transformation trajectories across regional industries. While several path development scholars have taken a regional approach (e.g., Miörner & Trippl, 2019; Trippl et al., 2020), our path dependence perspective see the interplay of structural components and state of the art technology as crucial in explaining the transformations observed in the empirical section. Thus, the analytical framework pays attention to how much technological trajectories diverge from technology existing in the regional industry context and the global technological state of the art, enabling a fruitful comparative dimension for studies of path transformation.

6. CONCLUSIONS

In this article, we have investigated the radicalness of industry path transformation in different geographical contexts by analysing the introduction of new technological trajectories within established industry paths (Boschma et al., 2017; Njøs et al., 2020). We have used an analytical framework based on path dependence theory and a typology inspired by Boschma et al. (2017) to conduct a comparative case study of the introduction of offshore farming technology in the salmon farming industry in coastal Norway and Tasmania to answer two research questions.

Our first empirical research question regards the similarities and differences in path transformation toward offshore farming within the salmon farming industries in coastal Norway and Tasmania. We show that Norway's path transformation is divergent from the region and the global state of the art through the creation of a novel technological trajectory. In Tasmania, the technological trajectory is less radical and, while divergent from the regional industry, is incrementally different from the sector state of the art technology. Our second theoretical research question explores how the agency of actors and structural components in regions can explain the radicalness of path transformation during windows of opportunities. We confirm that interplay of the agency of actors and structural components in regions have explanatory power for understanding path transformation, but that we need to include extra-regional industrial components, such as global technology trends, to achieve a more coherent analysis. This paper contributes to the path dependency literature by providing a more fine-grained view of path transformation raciness through our separation of the regional industry context and the overall technological state of the art.

Regarding policy implications, our empirical findings show how proactive policy regimes may trigger novel technological trajectories within an industry with differing radicalness. Policy may act as a triggering event, creating a window of opportunity for firms to transform a regional industry that may or may not fail based on regional structural components and the availability of network linkages to state-of-the-art technology. This article's findings also underline the importance of identifying regional competitiveness and mapping required regional capabilities to unlock radical technological trajectories in regional industries.

The study has some limits as it only a partial illustration of the transformation outcome typology of Boschma et al. (2017), leading to the need of future research to supplement the findings of this article. Further research on the interplay between agency and structural components during triggering events leading to windows of opportunity, such as uneven industrial responses to a global event such as the COVID-19 pandemic, may also be warranted. Finally, comparative case studies across different industry transformations but with similar technological trajectories could potentially be an exciting application for the approach outlined in this paper.

DISCLOSURE STATEMENT

The author certifies that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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NOTES

1 For more information on the Norwegian salmon farming industry, see Lindfors and Jakobsen (2022).
2 For more information on the Tasmanian salmon farming industry, see Fløysand et al. (2021).

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