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Sustainable regional industry development through co-evolution - the case of salmon farming and cell-based seafood production

Emil Tomson Lindfors [a,*], Stig-Erik Jakobsen [a]

[a] Western Norway University of Applied Sciences, Inndalsveien 28, 5063 Bergen, Norway

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ABSTRACT

Norway is the largest producers of aquaculture salmon in the world, and the Bergen region is the centre of Norwegian salmon production. In this article we explore the opportunities and obstacles in introducing cell-based seafood as a new related industry niche in the region through coevolution with the established salmon farming industry. Introducing a new industry niche to this region could contribute to a comprehensive renewal of existing seafood-related activity and represent a major step towards sustainable seafood production. Cell-based seafood may eliminate sea lice, escapee and excess nutrient impacts on the surroundings by enabling highly controlled and contained seafood production. We found that coevolution between the cell-based seafood sector and the salmon industry in the Bergen region will be difficult to materialize at the present time. There are two main explanations. First, coevolution is challenging when the dominant path (i.e., salmon farming) is in a stable state. High profitability and a stable state mean that this industry absorbs investors, technology suppliers and research milieus that may otherwise have been on the lookout for alternatives and supplementary business opportunities. It also means that incumbents within the dominant path will not be looking for diversification alternatives. Secondly, there are distinct differences between the two industry paths when it comes to knowledge base, innovation mode and geographical configurations, making actor mobility, knowledge spillovers and resource sharing between the two industry paths challenging. We also find that coevolution may occur in the future through industrial convergent evolution mechanisms of downstream value chains as the cell-based seafood industry matures.

1. Introduction

Aquaculture may help solve the grand challenge of reducing environmental pressures on the environment while feeding the growing human population though shifting consumption from beef toward seafood [1,2]. The ongoing strong growth of the aquaculture sector, and especially salmon farming, is commonly referred to as the "blue revolution" [3]. In 2050, this growth is expected to increase the seafood yield by 36–74% compared to current yields, primarily driven by mariculture expansion, such as salmon farming [4].

However, this expansion depends on the development of new products, technological innovation, policy regulation as well as future consumer preferences. On the one hand, salmon farming is important for economic growth because it stimulates increased volumes. On the other hand, the volume-oriented growth strategy has raised environmental impact concerns among consumers, politicians and others [5–7]. Managing and regulation of salmon farming can be considered a "wicked problem" due to the uncertainties of externalities [8]. Production areas for salmon are in short supply and reducing environmental impact of parasitic salmon lice and escapees or increase area though development of new production models is needed with increasing technological complexity [9].

Cell-based seafood is an emerging biotechnology industry that promises a new, disruptive seafood production that have garnered the attention of the aquaculture industry,[1] as well as European entrepreneurs,[2] as a promising novel seafood industry that may help feed the world. Public funded research on cell-based products has been initiated in Norway, for instance one project coordinated by Nofima, a research institution involved in salmon aquaculture research [10]. Research and innovation projects on new seafood niches is also seen as a key in the

* Corresponding author.
E-mail addresses: etli@hvl.no (E.T. Lindfors), sjak@hvl.no (S.-E. Jakobsen).

[1] https://www.nrk.no/nordland/denne-*laksen*-er-dyrka-i-eit-laboratorium-1.14606156

[2] https://thefishsite.com/articles/alternative-seafood-cell-based-seafood-in-the-european-union-bluu-biosciences-sebastian-rakers

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Norwegian aquaculture industry to achieve sustainable solutions to current growth and environmental challenges [11]. Cell-based seafood offer a novel approach to bridging the gap between production and demand, solving sustainability challenges associated with traditional salmon farming such as negating sea lice, escapee, and excess nutrient impacts on the surroundings by enabling highly controlled and contained seafood production. This technologically advanced production of seafood have origins other than traditional aquaculture, as techniques used in cell-based seafood were pioneered in other cell culture-based industries, such as pharmaceutics, cell-based therapies and regenerative medicine [12–14]. Seafood such as salmon fillets can thus be imitated at a cellular level, although due to the pilot-plant production stage of the industry, the performance of cell-based seafood in the market is still unknown [15]. Consumer acceptance of cell-based seafood have been linked to the acceptance of cell-based meat, where a recent review show that consumers identified animal and environmental benefits as well as health and food safety [16].

Salmon farming production in Norway reached 1.45 million tons and an export value of 7,9 billion USD in 2019 [17]. Norway is the leading salmon producer with the lowest production cost of all salmon producing regions [18]. This highly profitable industry has an extensive innovation system and innovation intensity [19] and plays an important role in the Norwegian government's sustainable ocean production ambitions. The Bergen region in Western Norway is the centre of the Norwegian salmon production industry, providing positive intra-industrial agglomeration effects [20]. The world's two largest salmon producers are headquartered and house their main operations in this region, along with other producers, suppliers, and world-leading marine research and educational institutions.

Many observers of industry development have argued that the introduction of a new, related industry, like cell-based seafood production, can be latent within previously existing industry activities in a region [21–23]. Technologies, competencies, resources, and practices from successful industry paths may spill over to related industry initiatives and subsequent industry paths. The notion of co-evolution has been introduced as an analytical category for such inter-connectivity between established and newly emerging industries [24]. In this article we explore the opportunities and obstacles in introducing a new related industry niche through co-evolution with an established regional industry. Salmon farming is the established industry and the cell-based seafood sector is the new industry niche, which we scrutinize for its development potential in the Bergen region in Western Norway.

While the salmon farming industry in the Bergen region's export orientation may give potential synergies in marketing and logistics and thus co-evolution potential [25], introducing a new industry niche to this region could contribute to a comprehensive renewal of existing seafood-related activity and represent a major step towards sustainable seafood production. Our empirical analysis is based on both document analysis and qualitative interviews with participants from the cell-based seafood industry and the salmon farming industry. As the salmon farming industry is exploring ways to diversify and increase sustainability though innovation [11], we have chosen to focus on the cell-based seafood industry due to news coverage on this rapidly expanding industry's potential to imitate seafood [15] which have garnered salmon farming industry interest.[3]

We start by presenting our conceptual framework (Section 2) before describing our methods and data (Section 3). In the empirical part (Section 4), we present the differences and similarities between the two selected industries before discussing opportunities for, and obstacles to, co-evolution. Finally, we link our empirical observations and the conceptual framework (Section 5).

[3] https://www.nrk.no/nordland/denne-*laksen*-er-dyrka-i-eit-laboratorium-1.14606156

2. Regional industry development

In order to understand industry development and the potential linkages between an established and a new industry branch in a region, we are using insight and concepts mainly from Evolutionary Economic Geography (EEG). This is a well-established perspective for analyzing changes in the economic landscape over time, within which the structure of the economy emerges from behaviors among entrepreneurs, firms and other actors [26]. The EEG perspective emphasizes how new growth dynamic and trajectories, defined as industry paths, evolve out of existing structural conditions and assets in a region [27,28]. Identifying new sources for sustainable growth and restructuring existing activities have become increasingly important policy issues, such that development of policy strategies to promote both renewal of existing industries and growth of new industry paths are required [27].

2.1. *Industry paths*

An industry path is a collection of firms that are related in the sense that they are all present within a value chain or use similar technologies or input factors [27], and along which self-reinforcing effects steer technology and industries along one trajectory rather than others [22]. An industry path includes entrepreneurs, firms, non-firm actors (i.e., different types of stakeholders), technologies and institutional circumstances (e.g. policy, regulations, supporting organizations [29]. The development of an industrial path follows the twin processes of continuation and change [1]. Continuation is linked to the concept of path dependent industry development. The mechanisms promoting path dependent industry development include sunk cost, economies of scale, investment irreversibility, technology specialization, development of agglomeration advantages and the establishment of a specialized structure of local suppliers [28,30]. Path-dependent development may also leads to technological lock-in: how industry development may eventually become locked in to specific technological trajectories [31]. Change processes, on the other hand, are associated with innovative practices among firms, entrepreneurs and non-firm actors.

The development of an industry is a sequential process. In some phases the industry may be dominated by dynamics and processes of change, characterized by technology pluralism and a high number of entrants and exits among industry actors. In other phases the industry can be in a stable state. This implies a hegemonic position for a selected technology, standardized products, an industry structure dominated by large corporations and a well-functioning policy support structure promoting 'more of the same [22].

2.2. *Knowledge bases, innovation modes and geographical configuration*

Knowledge is essential for industry development. Knowledge includes routines, skills and know-how, as well as explicit and systematic facts and information, which are key resources for the innovativeness of firms and industries [32]. Different industries are characterized by different knowledge combinations. A primary distinction between analytical and synthetic knowledge bases has been made within EEG [33]. An analytic knowledge base consists mainly of codified knowledge developed through formal procedures (codified knowledge being the explicit, systematic knowledge found in written sources such as textbooks, manuals and plans), which is thus transferable across distances. By contrast, a synthetic knowledge base refers to knowledge gained through experience and practical work. The latter has a distinct tacit dimension [34]. This is informal knowledge that has not been documented or made explicit by those who possess and use it and it has a certain degree of uniqueness [32]. In the literature, knowledge bases have often been portrayed in their 'pure' forms, and it has been argued that industries tend to be dominated by either an analytical or a synthetic knowledge base [33].

Knowledge bases are closely linked to the specific modes of innovation practiced by firms in different industries. Two ideal innovation modes have developed within the EEG literature [35]: STI (i.e., Science, Technology and Innovation) and DUI (i.e., Doing, Using, Interacting). Since research and development (R&D) is critically important to STI, this innovation mode relies heavily on an analytic (codified) knowledge base. Alternatively, DUI highlight the importance of interactions between customers and suppliers. Thus, this innovation mode is based on experience and competence gained through everyday work operations (i.e., a synthetic knowledge base). STI is more common in scientific-based and knowledge-intensive industries, while DUI is widespread in resource-based industries [36].

Industries can also differ according to their geographical configuration. Some industries are dominated by regional actors and networking between regional firms, while others has stronger presences of knowledge and technologies developed in extra-regional and global networks [28,37]. Binz & Truffer (2017) have introduced a typology of different geographical configurations for industries and differ between industries with a spatially sticky innovation system and industries with a 'footloose' innovation system [38]. In spatially sticky system, both innovation, networking and valuation processes depend on regional embedded conditions and the system is dominated by a DUI modes of innovation. Some extra-regional linkages also existing, and the system can be connected to global value chains. Resource-based industries often exemplify such a spatially sticky innovation system. In a 'footlose' innovation system there are 'globally valid dominant design and quality standards' that will homogenize valuation dynamics [38]. Innovations are developed in international networks and communities and are oriented towards mass production and economies of scale. Typical empirical examples of industries with footloose innovation systems includes pharmaceutical and software production.

2.3. Co-evolution between industry paths

In addition to these intra-industry characteristics, we must also investigate inter-industry dynamics, or the interactions among industry paths [39]. The notion of co-evolution was introduced as an analytical category to explain how technologies, competencies, resources and practices from successful paths may spill over to an emerging industry path [24]. Thus, co-evolution is an important factor in the dynamic emergence of a new industry niche and explains the connections among regional industry paths. The literature differentiates between co-evolution within an industry path (e.g., between the subsystem and institutional subsystem of firms) and co-evolution between industry paths [40]. The latter is the most relevant for our study. [21] analyzed the co-evolution of Norwegian salmon and cod farming, concluding that historical development within a path can lead to strong institutional specialization, and that knowledge and practices do not necessarily spill over to adjacent paths.

Despite the growing conceptual popularity of co-evolution, there is a scant literature on the main conditions under which it occurs [24]. It is important to know what factors co-evolve and why potential co-evolution materializes between adjacent industry paths, or not, in given situations [40]. For instance, there is limited understanding of how the maturity, knowledge bases, innovation modes and spatial configurations of industry paths impact on how two paths connect and on the type of inter-path couplings that may be developed.

Much of the EEG literature has discussed co-evolution between related industry paths that are co-existing. In our case, one of the industry paths, is in a very early stage. However, we turn to the concept of convergent evolution within biology to add explanatory power for the potential for co-evolution between an established industry path and a potential new industry niche in a region. Convergent evolution is a common mechanism in biology where organisms with differing origins will independently evolve similar morphological traits when facing isomorphic selection pressures from e.g. similar ecological niches.[41,42].

Similarly, while the origin and development status of two industry paths may vary, global isomorphic selection pressures, such as a global market forces, can produce similar innovations. This may open up for future collaboration and inter-path couplings since market characteristics, value chains and knowledge systems start to overlap. Recent findings have for instance shown that more efficient value chains within the Norwegian salmon farming industry may benefit the downstream activities of other related and non-related industries [25].

Cell-based seafood may reap the benefit of this development, and this may illustrate a process of industrial convergent co-evolution, ie. two industry paths evolving similar characteristics through the adaptation to generic selection pressures such as global market forces. Through analyzing the potential co-evolution between cell-based seafood and salmon farming in the Bergen region, our article expands our insight into how industry characteristics influence co-evolution processes between industry paths.

3. Materials and methods

Case studies of both the salmon farming industry and cell-based seafood industry have been conducted. Case studies can confirm, and nuance, theory-based assumptions. Herein, we elaborate on the EEG concepts and assumptions of path-dependent industry development and co-evolution. A main strength of qualitative case studies is their high level of conceptual validity, as they offer in-depth examinations of qualitative indicators and variables. Qualitative case study is appropriate for research that aims to contribute new knowledge on complex causal relations and to nuance theoretical assumptions [43].

From a theoretical basis, we set out to investigate the potential for co-evolution between an established industry path and an emerging path. Salmon farming in the Bergen region and cell-based seafood serve as typical cases through which we can gain a more general understanding of this phenomenon [44]. Data were collected through both document studies and semi-structured in-depth interviews. Documents included news coverage and salmon industry and cell-based seafood white papers. Online news articles and social media posts (e.g., LinkedIn) were monitored for both industries during the first two quarters of 2019.

We also conducted in-depth, semi-structured interviews with nine representatives in director like roles, such as managing-, program- or science director, from both salmon farming and cell-based seafood. The interview length ranged from 30 min to 120 min and were conducted in person, except one interview conducted over telephone due to rescheduling. Interviews were conducted between February and April 2019. Key informants were selected from both industries based on their in-depth knowledge of respective industry. Cell-based seafood industry actors were interviewed in San Francisco, USA, while aquaculture industry actors were interviewed in Bergen, Norway. Five informants from the Bergen region's salmon industry were interviewed, including representatives from two network organizations and three industry actors. Cell-based seafood, a more footloose industry, has not yet been established in the Bergen region. As such, we interviewed five industry actors, all of whom were at the time headquartered in the United States of America (USA) but with plans for expansion into other regions, such as Europe. Audio recordings of interviews were made with participant agreement, and later transcribed by a combination of automation software and manual transcription by the authors.

4. Empirical analysis

4.1. Characteristics of the two industries

In Norwegian aquaculture, Atlantic salmon represents the overwhelming majority of farmed species, in terms of both value and biomass, with a production of 1.45 million tons and an export value of approximately $7,9 billion USD in 2019 (compared with approximately 3500 tons of other marine species) [17]. These 1.4 million tons of

Norwegian farmed salmon constitute more than half the total global Atlantic salmon supply.

Over the past decade, Bergen has begun to be recognized as both a national and global centre for salmon farming. This region includes all the municipalities in Hordaland County,[4] with a population of approximately 520,000 inhabitants [45]. Fifty-seven salmon and trout production companies operate within this region, which is the largest number in any Norwegian county [46]. The two largest salmon producers in the world, Mowi and Lerøy Seafood Group, are headquartered in the Bergen region.[5] Moreover, the region has a strong marine research environment, led by the University of Bergen and the Institute of Marine Research. These research institutions established the 'Ocean City Bergen' initiative, emphasizing Bergen's world-leading position as a marine research and industry cluster; the importance of this region can also be measured by the volume of marine science publications by these institutions [47]. The University of Bergen was also selected as the official 'Hub Institution' for Sustainable Development Goal 14 (Life Below Water) by the United Nations Academic Impact (UNAI).[6] In addition, the Bergen region is the site of the publicly funded cluster organization NCE Seafood, which represents more than 70 industry actors and has a goal of promoting sustainable growth by strengthening collaborations among firms, and between firms, entrepreneurs and R&D institutions, within the seafood sector.

Cell-based seafood and the larger cell-based meat industry consist of over 70 startups and 40 life science firms backed by cumulative investments topping $350 m USD in 2020 [15]. Cell-based seafood is a subsection of the clean meat, or cell-based meat industry. This industry is based on tissue engineering, including cultured meat and leather systems in which cells or cell lines from living animals are tissue engineered to produce usable tissues. These tissues have minimal quantities of animal tissue input compared with livestock methods in which the cells themselves form the product. Starting materials (i.e. cells) can be biopsied from an animal [12]. [13] argue that the development of biomedical engineering combined with modern aquaculture techniques, such as genetic modification and closed system aquaculture, can pave the way for innovations in cell-based seafood production. These authors have stated that hypoxia tolerance, high buffering capacity and low-temperature growth conditions for marine cell culture, as well as the availability of waste products from aquaculture (e.g., chitosan), make cell-based seafood production promising. Cell-based seafood is not necessarily tied to a specific region, and interest in establishing cell-based initiatives is developing around the world. There have been some historic centres where the clean meat industry developed, such as San Francisco. Although much of this development now occurs within rapidly expanding early phase companies spread around the world.

The cell-based seafood production has been touted as a novel way of improving the sustainability of seafood production as it carries none of the environmental risks of salmon farming, such as salmon lice and escapees [8] as well as improving animal welfare by producing salmon without animals involved in closed containment systems [13]. On the other hand, the novelty of the industry also carries a high degree of uncertainty. Cell-based seafood need to achieve close to price-parity with incumbent seafood products, where high value species such as salmon may be more likely in the short term, but ultimately it is unknown when and if price parity is reached. Regulations and national approvals for this novel industry are still missing, recent regulatory approvals in Singapore for cell-based meat is paving the way for products to entering the market in 2021 [48].

Salmon farming in the Bergen region is a mature industry with a specialized value chain, a stable and tested technology, a well-established regulatory framework, and highly competent R&D institutions. It is an industry path in a stable state, dominated by a few large industry actors with global operations [49]. The open-net pen technology of the industry was introduced in the early 1970's and through incremental improvements it has become a cost-efficient technology for salmon farmers. New production technology has been developed and piloted by industry actors during recent years owing to a government initiative to develop solutions that minimize the industry's environmental impacts [27]. However, open-net pen technology is still the preferred option for almost all of the farmers, and thus the industry is characterized by a certain degree of technological lock-in. While salmon production is stable, significant changes in downstream are seen as salmon supply chains are developing in the same direction as supply chains for more processed food products [50,51] such as cell-based seafood.

There is interest from the aquaculture industry, entrepreneurs, intermediary organizations as well as environmental NGOs to establish ethical and sustainable novel salmon production systems such as cell-based seafood. These visions and expectations are not only descriptive of future potential technologies, but also generative [52]. The future is mobilized by the marshaling of resources, coordinate activities, and the common anticipation of future technology become connected through agents ideas about technology and technical opportunities [53,54]. New industry paths emerge not only from technological relatedness, but also from distributed agency and common visions about future development [55]. Thus, while cell-based seafood is still in a preformation phase in the region, the interest and vision from a plurality of actors can be formative and may initiate a viable future industry path.

Though there is interest in developing this industry path in the Bergen region, to date no trigger point for its establishment has been reached. It is reasonable to assume, based on reviewed documents and our interviews, that large-scale production is possible. The key bottleneck is the industry's ability to compete with traditional salmon farming in terms of production cost and value chain maturity. Production cost is mainly driven by the cost of growth medium, and thus one can argue that the trigger point for the cell-based seafood industry will be the development of media that is sufficiently inexpensive as to bring down production costs.

The knowledge bases for these industries also have distinct origins. The region's salmon aquaculture industry is based mainly on experience-based knowledge and a hands-on approach. Knowledge is generally transferred by word of mouth and through business-to-business interactions. This exemplifies a synthetic knowledge base. Yet some industry activities are more analytical knowledge-based, such as production of feed and vaccines and other efforts towards solving environmental issues. By contrast, cell-based seafood industry activity is based strongly on research and carefully measured experiments that are conducted by scientists at research institutions. This type of knowledge is codified and transferable, exemplifying an analytical knowledge base.

When it comes to innovation modes, the Bergen region's salmon industry is quite practical and production oriented. Much of its innovation activity is the DUI type, in which experience and tacit knowledge dominate, and incremental product innovations is the main output. The STI mode elements are mainly linked to innovation collaboration projects between the industry and R&D institutions. By contrast, the cell-based seafood industry is highly dependent on an STI mode in which much of the research and technology are developed in-house among the main industry actors. These firms are also more frequently involved in innovation collaboration with R&D institutions, through testing, experimentation, and piloting new solutions.

Regarding geographical configuration, the salmon farming industry is clearly tied to coastal areas. The Bergen region has become globally positioned as a salmon hub through a combination of crucial, beneficial geographical factors that make salmon farming possible, as well as from governmental investments in R&D institutions and the region's

[4] Hordaland county is a part of the Vestland county as of 1.1.2020

[5] https://salmonbusiness.com/these-are-the-20-biggest-salmon-farmers-in-the-world/

[6] https://www.uib.no/en/sdgbergen/121381/uib-becomes-official-un-ocean-science-hub

development of a strong supplier industry. Together, these industry actors form a competitive cluster characterized by specialization, collaboration and knowledge sharing. Thus, the industry has developed a spatially sticky innovation system. By contrast, cell-based seafood production will not be strongly tied to any specific geographical area, as it will take place in facilities that can be established anywhere in the world with the required infrastructure (e.g., cell biology labs, knowledge, capital and skilled labour). Countries such as the US, the Netherlands, China and Japan all have startups, venture capital and/or governmental backing to support establishing the clean meat industry. Thus, clean meat is associated with a footloose innovation system (Table 1).

4.2. Opportunities for co-evolution

Through our interviews with cell-based seafood industry representatives, we discovered that they are interested in gaining access to knowledge and animal biology expertise from the Bergen region salmon cluster: "*their knowledge of fish embryology, fish genetics would be super helpful*" (cell-based industry actor). As the salmon industry has matured, the value chain has diverged into specialized companies occupying specific niches; thus, genetics companies may be of specific interest. Though not yet in the Bergen region, cell-based firms do have collaborations with aquaculture firms, which they need to access tissue samples for research on species such as the bluefin tuna: "*[…] we do collaborate with a big fish producer right now. […] they give us samples, which is huge. […] we also use their expertise in fish development biology*" (cell-based industry actor).

While the stage may be too early for collaborations with salmon farming firms, experts see potential for future collaborations with the mature downstream value chain of the salmon farming industry: "*[…] they [Salmon farmers] would be really great for packaging, advertising, marketing sales channels. […] they know all the grocery stores, they know how to sell fish, and who wants fish. They've done all the market research [including on] how fish is bought and sold*" (cell-based industry actor).

At this stage, other areas of potential collaboration with salmon industry actors in the Bergen region may be more relevant. Almost all cell-based seafood industry activity is centered around companies' R&D into launching their products on the market. Thus, a collaboration with marine research institutions in the Bergen region may be of interest: "[…] *scientific collaboration would be great*" (cell-based industry actor). There is strong marine research activity in the Bergen region, much of which is generically focused on aquaculture and wild fish production: "*I think that kind of expertise on the fish side of things is hugely important at this stage of the game because there are just so few people in the whole world with fish cell culture experience, or who understand fish genetics or fish cell biology or fish physiology*" (cell-based industry actor). Thus, the Bergen region's strong marine research environment and expertise are advantageous for triggering the development of a new, related seafood industry niche.

Other potential areas for collaboration with the Bergen region's salmon farming industry are down-stream value chain activities such as distribution and marketing. Being included in the distribution and marketing of a large, diversified seafood product portfolio would clearly be advantageous for the cell-based industry. It could speed up the introduction of cell-based seafood to consumers: "*If they see it as an important thing to be a part of an aquaculture industry, then it has to be seen as a fish product portfolio more than synergies in production*" (salmon industry actor).

Table 1
Selected industry path characteristics.

Industry	Path-development phase	Knowledge base	Innovation mode	Geographical configuration
Salmon farming	Stable state	Synthetic	DUI	Spatially sticky
Cell-based seafood	Preformation	Analytical	STI	Footloose

Salmon compete against other animal proteins, e.g., beef, through being a supposedly healthier and more ethical choice. Government and regulatory institutions within salmon farming are keen to promote sustainable seafood production as a better choice to red meat, which is another pull factor for the Bergen region, and Norway generally. While there has been no official statement regarding the Norwegian government's stance on cell-based seafood, it is plausible to assume that when the industry grows, there will be a positive response based on the environmental sustainability, production increase potential and animal welfare benefits of cell-based seafood while delivering a health profile closely matching that of farmed salmon. The introduction of cell-based seafood may also help diversifying the seafood industry portfolio in the region as well as providing knowledge "spill-over" effects from the biotechnological advancements in alternative protein production.

4.3. Obstacles to co-evolution

Actors in the Bergen salmon farming industry are still generally unfamiliar with the cell-based seafood industry, which is to be expected regarding a nascent industry without a proven market. This new niche is for the time being not an important contender in the seafood market, and the uncertainty regarding production costs affects the valuation of the product: "*It will highly depend on the cost of production in my opinion; how much of a market share it can get*" (salmon network actor). There are also valid questions about whether the industry will be able to scale up significant biomass production: "*You have to come down from one hamburger party to producing literally millions of pounds to get any sort of traction […] You need to reach out to people who consume fish weekly and get them on board*" (salmon network actor).

Since salmon companies have not yet seen large scale tangible product output from cell-based seafood startups, the potential for downstream collaboration (i.e., distribution and marketing) is difficult to evaluate: "*If you look at cell-based seafood, or if you look at cell-based meat, I'm not expecting it to be at a price point where these guys could really distribute it or sell it anytime soon*" (salmon network actor). When products are on the market, the salmon producers may be more interested in taking part in the cell-based seafood industry: "*If they can show that they can achieve what they have planned both in terms of cost and quality, then I'm not saying it's not interesting to have a look at and at least get a foot in*" (salmon industry actor). Salmon farming firms seem to be taking a wait-and-see approach regarding their relations with the cell-based seafood industry, though salmon farmers are keeping track of developments: "*I think it [cell-based seafood] can become something […] I am a bit split on the issue, but we don't want to be naïve because at the end of the day, the consumer decides*" (salmon industry actor).

Norway, and the Bergen region specifically, represent a small domestic market. The cell-based seafood companies will have to target large consumer groups to satisfy the production volume needed for profitability. To reduce transportation costs, this points towards production locations near larger consumer markets: "*Personally I think it's good if they [cell-based seafood startups] are closer to markets*" (salmon industry actor).

It can also be argued that the Bergen region lacks sophisticated venture capital and other risk-willing capital sources, which can disable startup companies that seek funding for new industry niches. The nascency of the startup environment also affects the number of startups present in Bergen. In the early phase of industry development, it is important to be co-located with other startups to promote learning and knowledge sharing. There is certainly potential for collaborating with this region's large, established salmon industry firms. Yet doing so can be problematic for small startups that are easily 'overrun' by large players: "*In such an early phase I think one would let them do their own thing and not be overridden by the large machines*" (salmon industry actor).

Finally, while the Bergen region has a huge environment within marine science, it lacks a research infrastructure more specialized for cell-based seafood: "*If you could build an ecosystem of the necessary lab space for smaller companies like us, it's basically something that has laminar flows that is affordable […] universities nearby […] money […] that's kind of the three ingredients that you need the most*" (cell-based industry actor).

5. Concluding remarks

Our objective herein has been to explore the opportunities and obstacles for introducing a new, related industry niche through co-evolution with an established regional industry. Empirically, we investigated industry development in the Bergen region of western Norway, with the cell-based seafood sector representing the new industry niche and the salmon industry representing the established regional industry.

Cell-based seafood has large potential to diversify the seafood sector and contribute to increased sustainability by providing highly controlled seafood production without animals. Large investments, entrepreneurial experimentation and interest organization initiatives have been undertaken globally to rapidly mature the industry niche. There are visions and expectations among actors connected to the potential of cell-based seafood and the observed interest in the Bergen region seafood sector may provide opportunities for industry co-evolution in the future.

However, our main observation is that co-evolution between the cell-based seafood sector and the salmon industry in the Bergen region are challenging at the present moment. Despite growing popularity of the co-evolution concept, there is scarce literature to explain why co-evolution between two adjacent industry paths can be difficult [24, 40]. Through our study we found two explanations for this. First, co-evolution is difficult when the dominant path (i.e., salmon farming) is in a stable state. High profitability and a stable state mean that this industry absorbs investors, technology suppliers and research milieus that may otherwise have been on the lookout for alternatives and supplementary business opportunities. It also means that incumbents within the dominant path will not be looking for diversification alternatives. Our findings echo observations by [56], who argued that the most productive and skilled workers and entrepreneurs in a region tend to flock to the most attractive regional industry. Second, heterogeneity between the two adjacent industry paths also makes co-evolution difficult. As cell-based seafood and salmon farming are both affiliated with the seafood sector, one might expect that cognitive and technological relatedness would promote co-evolution [23]. However, there are distinct differences between the two industry paths when it comes to knowledge base, innovation mode and geographical configurations at the present time, making actor mobility, knowledge spillover and resource sharing between the two industry paths challenging.

We also introduce the concept of industrial convergent co-evolution to discuss potential co-evolution between industry paths that at the present are unrelated. As the cell-based seafood industry matures more opportunities for co-evolution may occur as downstream value chains of farmed salmon and cell-based production may intertwine through convergent evolutionary mechanisms. The cell-based seafood industry aims to create similar products and reach similar customers as the salmon farming industry. Thus, the cell-based seafood industry may eventually imitate and utilize the established logistics and marketing system for salmon, making the value chain of the two industries more similar in the mature stages of industry path development.

Our study has implications for policy formulation. The Bergen region lacks some of the infrastructure needed for cell-based seafood to emerge as an industry path. The industry is reliant on specialized R&D facilities such as laboratories and other test facilities. Though there is a strong seafood R&D infrastructure in Bergen, with public research institutions and established pharmaceutical companies, these are markedly oriented to the needs of the salmon industry (i.e., development of more efficient feed, vaccines, and other pharmaceutical services). Thus, policy initiatives mobilizing for development of a new industry niche are needed.

In such path creating processes regional innovation support organizations can play a proactive role [57]. The regional interest organization NCE Seafood Innovation Cluster have for instance a particular interest in creating a more sustainable and diversified seafood sector in the region. They can connect large seafood firms with startups and research to access cutting-edge innovation as well as interfacing with European policy initiatives to ensure increased focus on sustainable seafood development. Vestlandets Innovasjonsselskap (VIS), a business incubator and technology transfer offices in the region, provide research infrastructure and expertise toward better integration between biotechnology and aquaculture. Cell-based seafood is a viable alternative to fulfill such ambitions. Moreover, these regional innovation support organizations should work towards triggering the interest for cell-based seafood among the region's established salmon farming producers and suppliers. This could unleash more resources towards innovation and experimentation, which would likely increase the probability of the development of a new industry path in the Bergen region. The result could be a more environmentally sustainable and diversified regional salmon sector, including both traditional salmon farming and an emerging cell-based seafood production. This would also make the seafood sector in the region more resilience to external turbulence triggered by governmental initiated growth barriers for salmon farming, changing consumer preferences or environmental challenges.

Our study was not without limitations. First, co-evolution has been investigated through the potential establishment of a new industry niche in a region. If cell-based seafood activities were already in place, we could have examined realized and unrealized co-evolution dynamics, rather than potential co-evolution dynamics. Future research should also include empirical studies in other sectors and regions, to gain a more comprehensive understanding of why potential co-evolution between adjacent industry paths does, or does not, materialize.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2021.104855.

References

[1] A. Fløysand, S.-E. Jakobsen, Industrial renewal: narratives in play in the development of green technologies in the Norwegian salmon farming industry, Geogr. J. 183 (2017) 140–151, https://doi.org/10.1111/geoj.12194.

[2] H.E. Froehlich, C.A. Runge, R.R. Gentry, S.D. Gaines, B.S. Halpern, Comparative terrestrial feed and land use of an aquaculture-dominant world, Proc. Natl. Acad. Sci. USA 115 (2018) 5295–5300, https://doi.org/10.1073/pnas.1801692115.

[3] T. Garlock, F. Asche, J. Anderson, T. Bjørndal, G. Kumar, K. Lorenzen, A. Ropicki, M.D. Smith, R. Tveterås, A global blue revolution: aquaculture growth across regions, species, and countries, reviews in fisheries science and aquaculture 28 (2020) 107–116, https://doi.org/10.1080/23308249.2019.1678111.

[4] C. Costello, L. Cao, S. Gelcich, M.Á. Cisneros-Mata, C.M. Free, H.E. Froehlich, C. D. Golden, G. Ishimura, J. Maier, I. Macadam-Somer, T. Mangin, M.C. Melnychuk, M. Miyahara, C.L. de Moor, R. Naylor, L. Nøstbakken, E. Ojea, E. O'Reilly, A. M. Parma, A.J. Plantinga, S.H. Thilsted, J. Lubchenco, The future of food from the sea, Nature 588 (2020) 95–100, https://doi.org/10.1038/s41586-020-2616-y.

[5] J.L. Bailey, S.S. Eggereide, Indicating sustainable salmon farming: the case of the new Norwegian aquaculture management scheme, Mar. Policy 117 (2020), 103925, https://doi.org/10.1016/j.marpol.2020.103925.

[6] E.A.N. Christiansen, S.-E. Jakobsen, Diversity in narratives to green the Norwegian salmon farming industry, Mar. Policy 75 (2017) 156–164, https://doi.org/10.1016/j.marpol.2016.10.020.

[7] N. Young, C. Brattland, C. Digiovanni, B. Hersoug, J.P. Johnsen, K.M. Karlsen, I. Kvalvik, E. Olofsson, K. Simonsen, A.-M. Solås, H. Thorarensen, Limitations to growth: social-ecological challenges to aquaculture development in five wealthy nations, Mar. Policy 104 (2019) 216–224, https://doi.org/10.1016/j.marpol.2019.02.022.

[8] T.C. Osmundsen, P. Almklov, R. Tveterås, Fish farmers and regulators coping with the wickedness of aquaculture, Aquac. Econ. Manag. 21 (2017) 163–183, https://doi.org/10.1080/13657305.2017.1262476.
[9] B. Hersoug, E. Mikkelsen, T.C. Osmundsen, What's the clue; better planning, new technology or just more money? - The area challenge in Norwegian salmon farming, Ocean Coast. Manag. 199 (2021), 105415, https://doi.org/10.1016/j.ocecoaman.2020.105415.
[10] Forskningsrådet, GrowPro-Sustainable bio-production of animal proteins for human consumption - Prosjektbanken, Prosjektbanken - Forskningsrådet. (2021). ⟨https://localhost:3001/project/FORISS/280381⟩ (accessed August 6, 2021).
[11] NCE Seafood Innovation, Annual Report 2020, 2021.
[12] M.J. Post, Cultured meat from stem cells: challenges and prospects, Meat Sci. 92 (2012) 297–301, https://doi.org/10.1016/j.meatsci.2012.04.008.
[13] N. Rubio, I. Datar, D. Stachura, D. Kaplan, K. Krueger, Cell-based fish: a novel approach to seafood production and an opportunity for cellular agriculture, Front. Sustain. Food Syst. 3 (2019), https://doi.org/10.3389/fsufs.2019.00043.
[14] G. Zhang, X. Zhao, X. Li, G. Du, J. Zhou, J. Chen, Challenges and possibilities for bio-manufacturing cultured meat, Trends Food Sci. Technol. 97 (2020) 443–450, https://doi.org/10.1016/j.tifs.2020.01.026.
[15] B. Bryne, S. Murray, 2020 State of the Industry Report - Cultivated Meat, The Good Food Institute, 2021. ⟨https://gfi.org/wp-content/uploads/2021/04/COR-SOTIR-Cultivated-Meat-2021–0429.pdf⟩ (accessed August 6, 2021).
[16] C. Bryant, J. Barnett, Consumer acceptance of cultured meat: an updated review (2018–2020), Appl. Sci. 10 (2020) 5201, https://doi.org/10.3390/app10155201.
[17] Statistics Norway, Aquaculture (terminated in Statistics Norway), Ssb.no. (2020). ⟨https://www.ssb.no/en/jord-skog-jakt-og-fiskeri/statistikker/fiskeoppdrett/aar/2020–10-29⟩ (accessed February 16, 2021).
[18] A. Iversen, F. Asche, Ø. Hermansen, R. Nystøyl, Production cost and competitiveness in major salmon farming countries 2003–2018, Aquaculture 522 (2020), 735089, https://doi.org/10.1016/j.aquaculture.2020.735089.
[19] O. Bergesen, R. Tveterås, Innovation in seafood value chains: the case of Norway, Aquac. Econ. Manag. 23 (2019) 292–320, https://doi.org/10.1080/13657305.2019.1632391.
[20] F. Asche, K.H. Roll, R. Tveteras, Profiting from agglomeration? evidence from the salmon aquaculture industry, Reg. Stud. 50 (2016) 1742–1754, https://doi.org/10.1080/00343404.2015.1055460.
[21] B. Aarset, S.E. Jakobsen, Path dependency, institutionalization and co-evolution: the missing diffusion of the blue revolution in Norwegian aquaculture, J. Rural Stud. 41 (2015) 37–46, https://doi.org/10.1016/j.jrurstud.2015.07.001.
[22] R. Martin, Roepke lecture in economic geography—rethinking regional path dependence: beyond lock-in to evolution, Econ. Geogr. 86 (2010) 1–28. ⟨http://www.jstor.org/stable/27806893⟩. accessed February 26, 2021.
[23] R. Njøs, S.G. Sjøtun, S.-E. Jakobsen, A. Fløysand, Expanding analyses of path creation: interconnections between territory and technology, Econ. Geogr. 96 (2020) 266–288, https://doi.org/10.1080/00130095.2020.1756768.
[24] J.P. Murmann, The coevolution of industries and important features of their environments, Organ. Sci. 24 (2012) 58–78, https://doi.org/10.1287/orsc.1110.0718.
[25] I. Gaasland, H.-M. Straume, E. Vårdal, Agglomeration and trade performance – evidence from the Norwegian salmon aquaculture industry, Aquac. Econ. Manag. 24 (2020) 181–193, https://doi.org/10.1080/13657305.2019.1708995.
[26] R.A. Boschma, K. Frenken, Why is economic geography not an evolutionary science? Towards an evolutionary economic geography, J. Econ. Geogr. 6 (2006) 273–302, https://doi.org/10.1093/jeg/lbi022.
[27] A. Isaksen, S.-E. Jakobsen, R. Njøs, R. Normann, Regional industrial restructuring resulting from individual and system agency, Innov.: Eur. J. Soc. Sci. Res. 32 (2019) 48–65, https://doi.org/10.1080/13511610.2018.1496322.
[28] D. MacKinnon, S. Dawley, A. Pike, A. Cumbers, Rethinking path creation: a geographical political economy approach, Econ. Geogr. 95 (2019) 113–135, https://doi.org/10.1080/00130095.2018.1498294.
[29] M. Henning, E. Stam, R. Wenting, Path dependence research in regional economic development: cacophony or knowledge accumulation? Reg. Stud. 47 (2013) 1348–1362, https://doi.org/10.1080/00343404.2012.750422.
[30] R. Martin, P. Sunley, Path dependence and regional economic evolution, J. Econ. Geogr. 6 (2006) 395–437, https://doi.org/10.1093/jeg/lbl012.
[31] P. David, Path Dependence, its critics, and the quest for "historical economics," (2001) 26.
[32] B.-Å. Lundvall, The Economics Of Knowledge And Learning, in: Research on Technological Innovation, Management and Policy, Emerald (MCB UP), Bingley, 2004, pp. 21–42, https://doi.org/10.1016/S0737-1071(04)08002-3.
[33] F. Tödtling, M. Grillitsch, Does combinatorial knowledge lead to a better innovation performance of firms? Eur. Plan. Stud. 23 (2015) 1741–1758, https://doi.org/10.1080/09654313.2015.1056773.
[34] R. Njøs, S.-E. Jakobsen, J.K. Fosse, C. Engelsen, Challenges to bridging discrepant knowledge bases: a case study of the norwegian centre for offshore wind energy, Eur. Plan. Stud. 22 (2014) 2389–2410, https://doi.org/10.1080/09654313.2013.843651.
[35] M.B. Jensen, B. Johnson, E. Lorenz, B.Å. Lundvall, Forms of knowledge and modes of innovation, Res. Policy 36 (2007) 680–693, https://doi.org/10.1016/j.respol.2007.01.006.
[36] R.D. Fitjar, A. Rodríguez-Pose, Firm collaboration and modes of innovation in Norway, Res. Policy 42 (2013) 128–138, https://doi.org/10.1016/j.respol.2012.05.009.
[37] A. Isaksen, Cluster emergence: combining pre-existing conditions and triggering factors, Null 28 (2016) 704–723, https://doi.org/10.1080/08985626.2016.1239762.
[38] C. Binz, B. Truffer, Global innovation systems—a conceptual framework for innovation dynamics in transnational contexts, Res. Policy 46 (2017) 1284–1298, https://doi.org/10.1016/j.respol.2017.05.012.
[39] R. Hassink, A. Isaksen, M. Trippl, Towards a comprehensive understanding of new regional industrial path development, Reg. Stud. 53 (2019) 1636–1645, https://doi.org/10.1080/00343404.2019.1566704.
[40] E.W. Schamp, On the notion of co-evolution in economic geography, in: The Handbook of Evolutionary Economic Geography, 2010. ⟨https://www.elgaronline.com/view/9781847204912.xml⟩. accessed November 20, 2020.
[41] D.L. Stern, The genetic causes of convergent evolution, Nat. Rev. Genet 14 (2013) 751–764, https://doi.org/10.1038/nrg3483.
[42] C. Patterson, Homology in classical and molecular biology, Mol. Biol. Evol. 5 (1988) 603–625, https://doi.org/10.1093/oxfordjournals.molbev.a040523.
[43] G.H.S.P. of I.R.A.L. George, A.L. George, A. Bennett, P. of E.A. Bennett, MIT Press,, 2005.
[44] J. Gerring, Case Study Research: Principles and Practices, Cambridge University Press,, 2006.
[45] Hordaland Fylkeskommune, Hordaland County Council, (2020). ⟨http://www.hordaland.no:8090/nn-NO/hordaland-county-council/⟩ (accessed February 16, 2021).
[46] Directorate of Fisheries, Atlantic salmon and rainbow trout, English. (2020). ⟨https://www.fiskeridir.no/English/Aquaculture/Statistics/Atlantic-salmon-and-rainbow-trout⟩ (accessed February 16, 2021).
[47] University of Bergen, Evaluation of the strategic priority area marine research and education at the University of Bergen, 2014. ⟨https://www.uib.no/sites/w3.uib.no/files/attachments/marine_report.pdf⟩ (accessed February 16, 2021).
[48] B.S. Halpern, J. Maier, H.J. Lahr, G. Blasco, C. Costello, R.S. Cottrell, O. Deschenes, D.M. Ferraro, H.E. Froehlich, G.G. McDonald, K.D. Millage, M.J. Weir, The long and narrow path for novel cell-based seafood to reduce fishing pressure for marine ecosystem recovery, Fish Fish 22 (2021) 652–664, https://doi.org/10.1111/faf.12541.
[49] H. Österblom, J.-B. Jouffray, C. Folke, B. Crona, M. Troell, A. Merrie, J. Rockström, Transnational corporations as "keystone actors" in marine ecosystems, PLOS ONE 10 (2015), e0127533, https://doi.org/10.1371/journal.pone.0127533.
[50] F. Asche, R.E. Dahl, D. Valderrama, D. Zhang, Price transmission in new supply chains—the case of salmon in France, Aquac. Econ. Manag. 18 (2014) 205–219, https://doi.org/10.1080/13657305.2014.903309.
[51] U. Landazuri-Tveteraas, F. Asche, D.V. Gordon, S.L. Tveteraas, Farmed fish to supermarket: testing for price leadership and price transmission in the salmon supply chain, Aquac. Econ. Manag. 22 (2018) 131–149, https://doi.org/10.1080/13657305.2017.1284943.
[52] M. Borup, N. Brown, K. Konrad, H.V. Lente, The sociology of expectations in science and technology, Technol. Anal. Strateg. Manag. 18 (2006) 285–298, https://doi.org/10.1080/09537320600777002.
[53] N. Brown, M. Michael, A sociology of expectations: retrospecting prospects and prospecting retrospects, Technol. Anal. Strateg. Manag. 15 (2003) 3–18, https://doi.org/10.1080/0953732032000046024.
[54] H. van Lente, A. Rip, Chapter 7. Expectations in technological developments: an example of prospective structures to be filled in by agency, Get. N. Technol. Together (1998) 203–229.
[55] C. Binz, B. Truffer, L. Coenen, Path creation as a process of resource alignment and anchoring: industry formation for on-site water recycling in Beijing, Econ. Geogr. 92 (2016) 172–200, https://doi.org/10.1080/00130095.2015.1103177.
[56] R.D. Fitjar, B. Timmermans, Relatedness and the resource curse: is there a liability of relatedness? Econ. Geogr. 95 (2019) 231–255, https://doi.org/10.1080/00130095.2018.1544460.
[57] R. Njøs, S.-E. Jakobsen, Cluster policy and regional development: scale, scope and renewal, Reg. Stud., Reg. Sci. 3 (2016) 146–169, https://doi.org/10.1080/21681376.2015.1138094.