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Investigating the potential for cell-based seafood production

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Master Thesis
Innovation and entrepreneurship
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Abstract

This master thesis is a comparative case study of the salmon industry path in the Bergen region and the emerging cell-based seafood industry. Cell-based seafood is an industry that is utilizing biotechnology to produce seafood in a process that is innovatively disruptive compared to traditional aquaculture such as salmon aquaculture. In this master thesis I interview key stakeholders from the cell-based seafood industry in San Francisco, USA and salmon farming industry in Bergen, Norway to characterize the cell-based seafood and salmon aquaculture to uncover differences and similarities. Through the analysis I intend is to uncover the potential for renewal of the seafood sector in the Bergen region through the introduction of cell-based seafood production. The thesis conclude that salmon aquaculture is a dominating industry path in the Bergen region that is based on a synthetic knowledge base and utilizes a DUI innovation mode while experiencing positive path lock-in. The cell-based seafood industry is based on analytical knowledge base and utilizes a STI innovation mode while in a pre-formatory industrial state. The thesis further concludes that the enabling opportunities for cell-based seafood establishment in Bergen outweigh the disabling obstacles and I therefore encourage the import of the cell-based seafood industry path to the Bergen region to renew the seafood sector. The thesis makes two main contributions to existing theory on path development and path creation within EEG.

Foreword

This master thesis is the culmination of three years as a bachelor student of aquaculture biology at the University of Bergen and a two-year master in Innovation and Entrepreneurship at the Western Norwegian University of Applied Sciences.

I would like to thank the interview subjects for their willingness to set aside time for a master thesis interview in what was often a very hectic period, and to the Mohn Centre for Innovation and Regional Development fellows Marit Eggen and Øyvind Midtbø Berge with their support and facilitation.

It has been challenging writing such a comprehensive master thesis alone, so finally I would like to thank my supervisor Stig-Erik Jakobsen for the excellent guidance and support that transformed the thesis into a structured readable format with a solid innovation theory fundament.

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1. Introduction

There is an urgent need to renew protein production to reduce greenhouse gas emissions and at the same time increase the quality and safety of protein for human consumption (Garnett, 2009). Consumers need to have a good eating experience of a protein that is maintaining or improving human health and well-being (Scollan, 2011). As the global population increases and many countries such as China are increasing their GDP, the world protein consumption is also expected to increase dramatically (Rabobank, 2017). Conventional protein production will have a hard time to keep up with the demand (Henchion, 2017) leading to increased demand in the protein analog market, which is expected to reach a value of 46 billion USD by 2020 (Business Wire, 2018).

One way of addressing the protein production issues is to shift the consumption of animal proteins from land-animal more toward seafood due to it being a superior source of various nutrients and contain n-3-polyunsaturated fatty acids that have been linked to the prevention of various diseases (Hosomi, 2012). Seafood is only 3% of total meat consumption, but the growth in the sector is outpacing land meat consumption where seafood is growing at 3.2% annually while all land-based sources are growing at 2.8% combined (FAO, 2018). Seafood protein production can reduce emissions and provide healthier foods which are meeting concerns by consumers who are increasingly aware of the food they consume. Humans can't synthesize omega-3, that means that we have to get it from food. The omega-3's (especially DHA and EPA) are a family of polyunsaturated fatty acids that are commonly found in seafood.

WWF states that over 85% of the world's fisheries are pushed beyond their biological limits due to overfishing, which can lead to stock collapses (WWF, 2015). There are many examples of stock collapses due to overfishing, but the most famous one is perhaps the collapse of the Atlantic northwest cod fishery in the '90s. The collapse is attributed to a mix between fisheries mismanagement, technological advancements, and disregard of the ecological impact. 33.1% of all stocks are currently overfished and it is unlikely that these stocks will be rebuilt in the near term (FAO, 2018). Instead of creating the human-driven 6th mass extinction due to over-harvesting wild stocks, aquaculture has the potential of supplying humans with seafood in a more sustainable way with a heavily regulated industry. A rapid 8% growth year for over 30 years, while fishery growth has been flat in recent years, means that in 2015 half of the fish destined for human consumption came from aquaculture (FAO, 2018).

Norwegian salmon farming is one of the most sophisticated large-scale seafood production systems in the world. The Norwegian seafood export in 2018 was 2.72 million metric tonnes valued at 99 bn NOK, an increase in volume by under 5% from 2017 and only a 17% increase over the last 10 years (Norwegian Seafood Council, 2019). The slow production increase is mainly due to policy-induced restrictions due to biological challenges in salmon and trout farming. Diseases, genetic impact of wild stocks and nutritional and medicinal leaking into the environment have been the main drivers for governmental restrictions (Ministry of trade, Industry and Fisheries, 2015). The challenges have been inducing new growth policies where technological and sustainable innovation in farming has been required.

Clean meat or cell-based meat is an emerging biotechnology industry that promises a new disruptive way of producing meat that can address many of the challenges in industrial production of meat and seafood. cell-based seafood can potentially address the industry growth issues in species such as salmon by providing a novel production method that theoretically can bridge the gap between production and demand and thus increase the global seafood consumption. There are multiple studies that have looked at the possibility of using clean meat to replace traditional farming of animals with multiple review articles giving a summary of the current state of the science, regulations and consumer acceptance for this industry. Many of the techniques used in clean meat production have been pioneered in other industries requiring cell culture such as pharmaceutics, cell-based therapies and regenerative medicine (Specht, 2018), but none have looked at the cross-industry potential with specific industries such as aquaculture to acquire knowledge needed for industry maturation.

The Bergen region is a core area for both seafood and salmon production in Norway. This region may also be a potential location for the new cell-based seafood production. The purpose of this master thesis is to investigate the potential for cell-based seafood production as a viable strategy for renewal of the seafood sector in the Bergen region. Though qualitative interviews with participants from both the salmon and the clean meat sector and through and theory informed empirical analysis, the thesis will adequately discuss the research questions presented in the next chapter.

1.1 Research Questions

The research questions in this master thesis are centered around examining two subject industries, the Norwegian salmon farming industry and the cell-based seafood industry to uncover their status, how they compare and if the industries can collaborate efficiently. The theoretical framework used is evolutionary economic geography (EEG), with a strong path dependency focus and additional innovation theory concepts needed to effectively analyze the research questions. I use four research questions; RQ1 focus on Norwegian salmon farming, RQ2 focus on cell-based seafood, RQ3 which is an industry comparison question, and finally RQ4 where I examine the opportunities for collaboration. The research questions are supplemented with assumptions to structure the thesis and give the reader tangible priors for the discussions in chapters 4-8.

1.1.1 RQ1: What characterizes the salmon industry path in the Bergen region

This first research question aims to examine the status of the salmon farming industry in Bergen, the importance of the Bergen aquaculture cluster to the industry as a whole, how mature the salmon farming industry is and to understand where the industry path is heading. Due to the agglomeration of aquaculture actors in the Bergen region such as major salmon corporates and world leading research and educational institutions in marine disciplines Bergen is strongly positioned to be a center for aquaculture on a global scale.

First Assumption: Norwegian salmon farming is mainly experiencing substantial incremental innovations

Norwegian salmon farming has been rapidly advancing over the last few years, and the young industry is facing strict regulations and increasing environmental challenges. The Norwegian government aims for salmon to become one of the country's’ future industries and has publicly declared that there is potential to increase production five-fold to 5 million tonnes annually by 2050 (Ministry of Trade, Industry and Fisheries, 2015). This governmental support to increase production as well as the current profitability of the salmon farmers gives an incentive to for incremental progress that will optimize the production and I thus assume that the Norwegian salmon farming is mainly experiencing substantial incremental innovations.

Second Assumption: The salmon farming industry path is in a stable state

The Norwegian salmon farming is a relatively new industry, with its first activity in the 1960's (PwC, 2019), but it has rapidly advancing and incremental innovations with governmental support to increase production and salmon farming profitability will lead to a stable state where the salmon farming industry is experiencing positive reinforcement mechanisms that will lead to little incentive to break away from the current industrial state.

1.1.2 RQ2: What is the status of cell-based meat and seafood industry?

This second research question aims to examine the status of the cell-based seafood industry, and uncover where the industry is agglomerating, the importance of San Francisco as a regional innovation system, the nascency of the industry and what likely cross industry knowledge the industry can obtain. Much of the recent activity in cell-based meat and seafood has been coming out of San Francisco, USA. This city which is adjacent to Silicon Valley has long been a hotbed for startups and innovation where disruptive innovations and world changing ideas are actively sought out by venture capitalists. The cell-based industry is very disruptive to a very large market, the animal proteins, and thus is of interest to the investors who may encourage the establishment of startups in this space.

First assumption: Cell-based seafood has considerable cross industry innovation potential with cognitive proximate established industries

There are no cell-based seafood products on the market today, and there are considerable technical challenges to reach market ready products (The Guardian, 2018). The cell-based seafood industry will need to look for knowledge in other industries that have related technology and processes to be able to scale up production and build up an intra-industrial knowledge pool on how to develop market ready products.

Second assumption: The Cell-Based seafood industry path is nascent and in an early pre-formation phase

As no products are on the market yet, there are still many unknowns. I assume that the cell-based seafood is in a very nascent state and cannot technically be called an industry yet since the industry itself is in an early pre-formation phase.

1.1.3 RQ3: What are the differences and similarities between salmon farming and cell-based seafood production?

The third research question explores how salmon aquaculture and cell-based seafood industries compare in different aspects such as the industry status and production methods. The two industries aim to produce approximately the same product but through different processes which may lead to differences between the industries.

First assumption: The production methods of cell-based seafood is significantly different from traditional aquaculture which leads to cognitive distance

The process of producing cell-based meat and seafood will only use animal sources as the starting point for the industry for the tissue extraction. When immortalized cell lines are established, the production of cell-based seafood will be more reminiscent of brewing beer or producing pharmaceuticals rather than animal farming. I assume this divergence in production lead to industrial value chains and processes that are significantly different from traditional aquaculture.

Second assumption: The cell-based seafood production is not geographically tied to a coastal area in the same way as salmon farming and thus has other location preferences

Salmon farming is producing fish in open-net pen cages and thus much of the value chain is tied to coastal regions where the environmental and regulatory factors for salmon farming is beneficial. Cell-based seafood on the other hand is not tied to a specific geographic area and is thus assumed to be free to locate based on other preferences. I expect these preferences to be tied to capital availability and a local biotechnological knowledge pool.

1.1.4 RQ4: What are the enablers and obstacles for renewal of the seafood sector in the Bergen area through cell-based seafood production

Finally, the fourth research question aims to answer if Bergen, as an aquaculture cluster may be a good location for the emerging cell-based seafood industry as an establishment could be mutual beneficial, where the Bergen region as a seafood capital could provide expertise and knowledge in exchange for establishment of a new industry that would generate new jobs.

First assumption: The strong marine research environment and salmon farming sustainability focus are enablers for cell-based seafood renewal in Bergen.

The supposed nascency of the cell-based seafood industry is assumed to require substantial scientific expertise and knowledge and could thus benefit from the strong research environment in Bergen. The salmon farming industry also has an environmental focus that may merge well with the sustainability benefits for cell-based seafood.

Second assumption: The salmon farming industry lock-in and cognitive distance to cell-based seafood are obstacles for cell-based seafood renewal in Bergen

I am assuming in RQ3 that the aquaculture industry and cell-based seafood have significantly different production and processes which in turn requires different knowledge, inputs and expertise that will lead to a cognitive distance between the industries. This cognitive distance together with the salmon farming industry lock-in assumption in RQ1 will both act as obstacles for locating the cell-based seafood industry in Bergen.

1.2 The structure of the thesis

This thesis is divided into nine chapters including introduction and excluding references. After chapter 1 which contains the introduction, the theory chapter 2 follows where my theoretical approach is presented. In the next chapter 3 the materials and methods for the chosen research design and data collection are described, followed by chapter 4 which is an introductory chapter to the two subject industries; salmon aquaculture and cell-based seafood where most of the collected secondary research is presented. Chapter 5, chapter 6 contain the presentation and analysis of the primary data collected through the interviews which describe the two industries. Chapter 7 is an industry comparison chapter where I compare the similarities and differences between the two industries, which is followed by chapter 8 where I present and analyze primary data on the enabling opportunities and disabling obstacles of establishing cell-based seafood in the Bergen region. The thesis wraps up in chapter 9, which contain the summary and conclusion where the main findings, theoretical contributions, practical implications and future research opportunities are presented.

2. Theory

Innovation theory is the study of innovation, which is widely considered to be the engine of growth in the economy (Trott, 2017). One of the earliest economists studying innovation in regard to economic growth was Schumpeter and in his book Capitalism, Socialism and Democracy from 1942, he referred to innovation as an evolutionary cycle of continuous innovation and destruction (Schumpeter, 1942). In this thesis I will focus on the overlaying systemic level of innovation theory where industries and the region are the central subjects and *evolutionary economic geography* as a force affecting the industries to shape their present status and future trajectories. The first part of the chapter presents the approach, before I discuss key concepts such as *industry path, co-evolution*, *knowledge bases*, *cross-industry innovation* and *path dependency*. Theoretical concepts are utilized in the analysis to argue the validity of the research questions outlined in section 1.1.

2.1. Evolutionary Economic Geography as theoretical perspective

The innovation process is one of the main engines of economic growth. This potential to create new products, processes, markets and organizations are tied to certain geographies that seem to have the innovation capabilities over time, as the capabilities are dependent on the accumulation and development of relevant knowledge (Trott 2017). Innovation does not usually simply occur randomly. A large body of research suggests that innovation is a highly localized phenomenon with strong ties to the economic, social cultural and institutional climate in a region, and can thus be tied to an industry path. Some regions seem more "enabling" when it comes to innovation, and regions that are fertile innovation nurseries will continuously produce innovations through innovation actors from the base conditions in the region, and will give birth to new industry paths that can be seen as spinoffs from the original industrial path (Martin, 2010).

The importance of regional embeddedness, or attachment is at the core of *Evolutionary economic geography (EEG).* It is a framework that effectively can be used to understand industry development in a region over time by merging the concepts of economic geography and evolutionary economics (Martin 2010). The development of new industries is understood as the emergence of new sectors and clusters though new market opportunities, spinoffs from established firms and entrepreneurial activities (MacKinnon et al, 2018). Identifying new sources of growth and restructuring of existing activities is also becoming an increasingly important policy question and thus requires development of new regional innovation strategies that foster new economic structural change (Isaksen et al 2017). In recent years the use of the evolutionary economic geography (EEG) framework has gained momentum as innovation is increasingly being placed in a regional context due to the success of innovation hubs such as Silicon Valley.

EEG is a way to analyze the changes in the economic landscape over time, where the spatial structure of the economy emerges from the behavior of individuals and firms in the landscape (Boschma and Frenken, 2006). The EEG perspective emphasizes how new growth dynamic and trajectories, defined as paths, evolve out of existing economic activities in a region in the context of the associated regional conditions and assets (Isaksen, 2014). Analyzing industrial development though the ECC lens gives us a toolbox with a rich palette of ideas and concepts to draw from such as variety, selection, fitness, retention, mutation and adoption from evolutionary biology and self-organization, co-evolutionary, emergence and criticality from complexity science. The application of paradigms from one science to another is a risky venture and care for appropriate ontological transfers is needed, but Morkyr, Metclafe and others argument that Darwinian models transcend biology and that evolutionary biology is just an application of a set of models that try to explain how certain kinds of systems evolve over time (Boschma and Martin, 2010). The concept of industrial development based on system history gives an understanding of industries in a broader context tied to regional and historical context which can give an understanding of the trajectory and future developments

Boschma and Martin (2010) outlines three major theoretical frameworks that have been identified for evolutionary economic geography. (1) Generalized Darwinism with concepts from modern evolutionary biology such as variety, novelty, selection, fitness, retention, mutation, adaptation and population dynamics. (2) Complexity theory with aspects of "far-from-equilibrium" adaptive systems: emergence, self-organization, adaptation, fitness landscapes and hysteresis. (3) Path dependence theory with the role of contingency and self-reinforcing dynamics, "lock-in" by increasing returns effect, branching and path creation (Boschma and Martin, 2010).

One of the most used notions in economic geography is path dependence which describes the economic landscape as not being of some predetermined equilibrium or state but more of an open system that is shaped by its past developments. This thesis will be focusing on the theoretical framework of path dependence theory as our analysis will be at the system level focusing on industries rather than individuals, with the assumption that our chosen industries aquaculture and clean meat can be understood as two separate industries.

2.2. Key dimensions within EEG

2.2.1 Industry path

An industry path is a collection of a number of firms that are related in the sense that they might be present in related value chains, use similar technologies or use similar input factors (Isaksen et al 2017) where self-reinforcing effects steer technology, and industry or regional economy along one path rather than others (Martin, 2010). The industry path includes firm populations, dominant technology and institutional arrangements such as regulations, policies and supporting organizations. An industrial path exists through a finite timescale and contains persistent institutional and industrial structures and economic agents that continue their activities as conditions are changing (Henning et al, 2013).

Innovation actors are key components to the innovation process of an industry path and can be divided into two different subcategories: (1) Intrapreneurs are innovation actors inside established organizations where typically scientist, managers and researchers engage in innovative activities through the development of new products. (2) Entrepreneurs on the other hand are not tied to organization and the traditional view of entrepreneurship is of an individual who spots an opportunity and develops a business (Trott, 2017). Howard Stevenson defines entrepreneurship as: "the pursuit of opportunity beyond the resources you currently control" (Stevenson and Amabile, 1999). These innovation actors can affect industrial paths by creating new paths through disruptive technological innovation events.

2.2.2 Different knowledge types

Knowledge is often divided into two distinct parts, or dichotomies (Jensen, 2007), such as *tacit knowledge* versus *codified knowledge*, *analytic knowledge base* versus *synthetic knowledge base* or *Science, Technology, Innovation (STI)* versus *Doing, Using, Interacting (DUI)*. These concepts often intertwine.

At a fundamental level knowledge can be divided into information that is written down and transferred between actors, such as instructions, which is called codified knowledge and tacit knowledge which is knowledge that is difficult to verbalize or write down and is connected to skills, ideas and experiences. Building on that fundament is the knowledge bases which take other factors into account as well such as spatial proximity, the sources of knowledge and innovation concepts such as radical and incremental innovation. An *analytical knowledge base* is insensitive to spatial proximity and is based on scientific inputs with deductive processes and formal models. The knowledge is strongly codified and based on laboratory-based research and can often lead to radical innovation by creation of new knowledge (Plum 2011). A *Synthetic knowledge base* on the other hand, has spatial proximity of high importance, is a more applied problem related knowledge base where inductive processes and "learning-by doing" is utilized. The tacit knowledge leads to incremental innovation by application or combination of existing knowledge through processes such as testing, fine-tuning and system design (Plum 2011).

In a paper from 2007, Jensen et al. analyzed firms in the Danish economy and their usage of two ideal types of innovation modes and learning to understand how firms innovate and communicate. The first mode was a codified scientific and technical knowledge mode is referred to as *Science, Technology and Innovation (STI)*, where know-why knowledge is acquired through experiments and interpreting results that derives from a global knowledge and form generalized codified knowledge in the form of licenses and patents. The second mode was a more experience-based tacit knowledge mode is referred to as *Doing, Using and Interacting (DUI)* where know-how and know-who knowledge is formed from extensive practical knowledge and problem-solving on the job when an obstacle occurs which generates highly localized knowledge through organizational activities such as relationship building project teams and product/solving groups. The paper concludes that firms are characterized by primarily either a DUI or a STI innovation mode, and that firms may adopt both modes but that they may not coexist harmoniously (Jensen 2007). Firms practicing the DUI-mode are basically using synthetic knowledge, while the STI-mode is closely associated with analytical knowledge. Parrilli and Heras (2016) echo Jensen (2007) and emphasis the importance of a combined STI&DUI mode for effective and greater innovation output as STI has a strong effect on technological innovation but DUI has strong impact on non-technological innovation (Parrilli & Heras, 2016).

Fitjar and Rodriguez-Pose (2013) examine innovation modes in Norway and introduce a geographical attachment component to analyze the importance of local ties in innovation. The paper concludes that interaction with local agents have little impact on innovation potential except STI-type interactions with universities, but engagement with external agents however was more closely related to firm innovation as repeated knowledge exchanges with local heterogeneous actors is not generating enough variability for innovation. (Fitjar & Rodriguez-Pose 2013).

Knowledge transfer required a certain capacity to identify, interpret and exploit new knowledge (Nooteboom, 1999). This absorption of new knowledge by actors and firms is dependent on a cognitive proximity so that the communication, processing and understanding of knowledge is close enough for a successful transfer (Martin, 2010). Boschma (2005) recognizes cognitive proximity one out of five proximity dimensions, the others being: organizational, social, institutional and geographical proximity. Using the cognitive proximity in an EEG context can increase the understanding of how likely industries are to connect and transfer knowledge dependent on how proximate their knowledge bases are. *Cognitive Distance* is another related term used to describe nearness between entities. Nooteboom (2007) describes as optimal when firms have a cognitive distance that is not too large nor small and thus gives optimal opportunities for combination of complementary resources and knowledge. One can anticipate that will be a certain knowledge distance between an industry path that is based on analytical knowledge, versus an industry path that mainly has a synthetic knowledge base.

2.2.3. Linkages between firms and industries

Co-evolution is an important factor in the dynamic emerging of a new sector, technology or industry and can be utilized to address dynamics such as inter-industrial relationships between firm populations and their converging processes (Aarset & Jakobsen, 2015). For co-evolution to exist it must be possible to differentiate between two populations that at the dependent on reciprocal causality (Martin 2010). The term is adapted from primary biology and features the evolution of two populations that have significant causal impact on each other's ability to persist (Murmann

2003). According to Martin & Sunley (2006) certain kinds of co-evolution within sub-systems of an industry path are essential in positive lock-in situations.

Co-evolution between industry paths is a notion that is useful for understanding the connection between industry paths. The status of the paths, if they are emerging, mature or declining will have an impact on how two paths connect and their inter-path couplings. A paper by Aarset & Jakobsen (2015) analyzed the co-evolution of two aquaculture industry paths; salmon-farming and cod-farming where it was concluded that co-evolution within a path can lead to strong specialized institutional arrangement that creates a positive lock-in environment that does not necessarily spill over to adjacent paths.

While the concept of co-evolution is associated with linkages and knowledge flow between systems, the concept of cross-industry operates at the firm level. Imitating and retranslating solutions from other industries into the company's current market or products is called cross-industry innovation (Enkel & Gassman, 2010), and in its core is a concept very much aligned with Schumpeter's famous observation that most innovation is a recombination of existing knowledge (Schumpeter, 1939). The main utilizers of cross-industry innovation are large which do so to reduce the time to market and increase their innovativeness (Enkel & Gassmann, 2010).

Many articles have researched cognitive distance as one of the key factors when evaluating the cross-industry potential. It has been suggested that there is an inverted U-shaped relationship between cognitive distance and innovation performance. Because when people with different knowledge interact, they stimulate a stretching of knowledge to bridge the gap between both knowledge pools (Nooteboom, 2007). The U-shape means that a certain degree of cognitive distance enhances the opportunity for novel combination while too much cognitive distance leads to misunderstanding (Gulati, 1995).

To understand the effects of cross industry innovation one must also explore the effects of the innovation. The innovation context can be either exploratory (disruptive innovation) or exploitory (incremental innovation) where Enkel & Gassmann (2010) found that there was no significant correlation between cognitive distance and the innovation context.

2.3. The industry development process as path dependent

Path dependence theory has its roots in EEG and thus takes evolutionary concepts of history as a significant influence on current industrial activity in the region. These historical developments in the region is visible in the formation of the industrial structure, culture, technological dominance, and human capital specialization in the region (Isaksen, 2017).

Path dependence is a multi-scalar process that operates on different levels in the economic landscape, and can refer to a regions firms, industries or the region economy as an aggregate. The mechanisms of which regional path dependence works in regional economies can be sources such as sunk cost in infrastructure, industrial localization, agglomeration economies, cultural-institutional embeddedness and local economic linkages. Regions may also contain multiple paths and these paths may co-exist and display a inter-path coupling, which may increase the complexity (Boschma and Martin, 2010). Through the path dependence theory lens, a regional industrial path is a course of interrelated events where technology, institutions and/or organizations gain momentum in a region (Sydow et al, 2012). In this thesis our focus is on the industrial level, where certain events have triggered a self-reinforcing series of following events that makes up the industrial path.

Industries in certain regions may be more or less path dependent, David (2001) has classified the historical influences of a path on an industry as weak, moderate and strong. and different regions will have their own particularities, which affects the translatability of events when comparing two regions. To understand industry evolution as path dependent I take the position of Martin (2010), Jakobsen et al (2012) and Njøs, Jakobsen and Rosnes (2016) that the development of an industrial path should follow the processes of continuation and change. The continuation process can be seen as the self-reinforcing process that is described as defining for an industry path. Change processes are associated with the practice of intrapreneurs, i.e. innovations within existing firms, and entrepreneurs, i.e. new entrants to the industry.

2.3.1 Path lock-in

The core construct of path dependence theory has historically been the lock-in model used by many authors to characterize localized forms of industrial specialization where increased returns effect, build-up of localized pool of skilled labor, local knowledge spillovers, development of interfirm labor division and other interfirm dependencies (Martin 2010). The traditional lock-in process from Martin is derived from the works of Paul David and Brian Arthur who both are prominent figures in path dependence theory and are credited to have introduced the concept with e.g. David (1985) and Arthur (1989). Martin (2010) compiled the processes that generate lock-in; David's models of "network externalities" with (1) Technical Interrelatedness, (2) Economies of scale, (3) the quasi-irreversibility of investments and Arthurs Model of "increasing returns effect" with (1) Large initial fixed setup costs, (2) Dynamic learning effects, (3) coordination effects, (4) self-reinforcing expectations.

The effect of the lock-in process can both be positive and negative, depending on the stage of development of local industrial clusters, as suggested by Martin and Sunley (2006). Lock-in can be positive for early stages of industrial development where the increasing return effect and agglomeration economies benefit the industry. In later stages of industrial development, the lock-in can be negative due to hindrance of continued growth and renewal which in turn can lead to loss of competitiveness.

2.3.2 The dynamic path dependency model

While the lock-in model has long been a core process of path evolution Martin (2010) criticizes the rigidity of this lock-in model where path dependency, since it seemed to only matters when the technology or industry has already emerged but has no impact on its emergence or where it takes place, and that de-locking only will take place when an external "shock" takes place such as a financial crisis or a disruptive innovation event and not as a continuous evolution where the path itself transform through dynamic processes such as layering, recombination, conversion and structured variety.

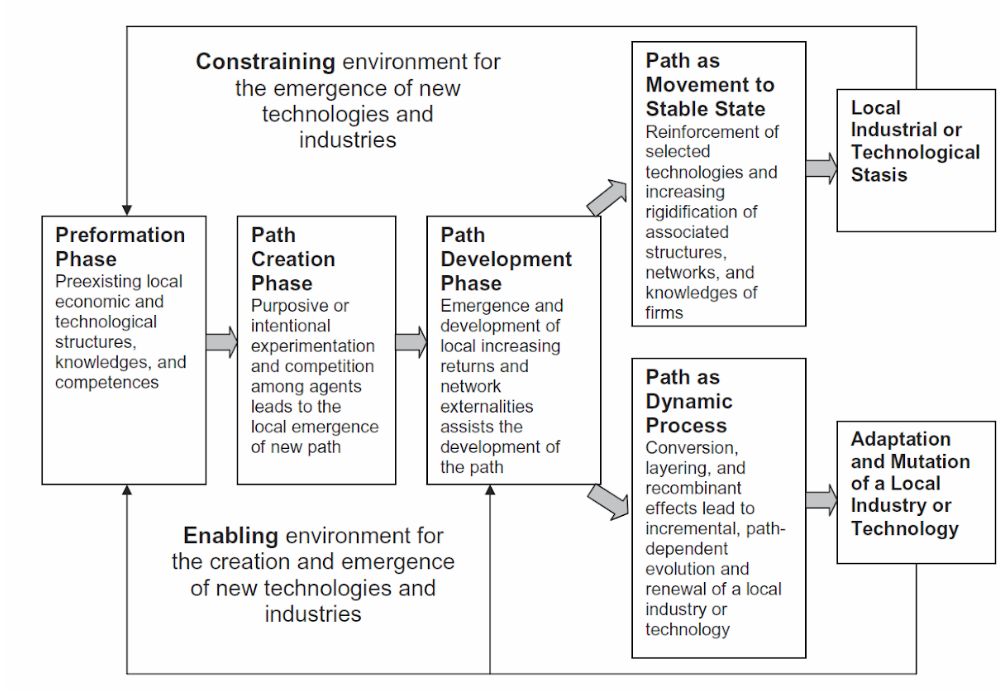

Figure 1. "Toward an alternative path dependence model of local industrial evolution", Martin 2010 s.21

In his 2010 article Ron Martin proposed a new model for path dependence, as shown in figure 1, where the lock-in concept is mixed with a new dynamic process of evolution that infuses concepts from EE such as variety, selection and fitness into the model. In his model the external conditions in the regions will create what is called an "enabling" or "constraining" environment, which separate the industry development process into two distinct tracks.

In both tracks, the industry path starts a preformation phase from pre-existing local conditions such as knowledge, competence and technological structures which lead to a path creation phase where competition, experimentation lead to path emergence. After the path development phase, where local returns and network externalities impact the path development the tracks split into either (1) a stable state path, which is characterized as the traditional lock in model with rigid structures and reinforcement due to a constraining environment which lead to industrial stasis (2) a dynamic path where the previously mentioned dynamic processes take place due to an enabling environment which lead to adaptation and mutation of the industry.

Industries develop and evolve through adaptation to the ever-changing environment where the market, competition and regulation acts as selection pressures. Martin argues that though the new alternative path dependence model the ontology of path dependence can move closer to an evolutionary ontology, and thus gives us a better framework to link to evolutionary economic geography.

2.3.3 Path extension, creation upgrading and diversification

In the standard path dependence model, the process of path creation starts with chance events leading to a path becoming "locked-in" to configurations and technologies that can only be "de-locked" by an external shock or disturbance (Martin, 2014). The creation of a new path in newer path dependence theory is based on the notion that paths do not start from nowhere but are instead heavily influenced by the EEG in the region. Isaksen et al. (2014) differ between four distinct development paths for an industry: 1) *Path extension* as reproduction of existing economic trajectories through incremental innovation adjusting to external conditions, 2) *Path exhaustion* involves the decline and erosion of established paths due to a failure to adapt to change through a lock-in mechanism, 3) *Path renewal* occurs when economic actors move into a related field through diversification and regional branching. It can also occur through technological upgrading of an industry. 4) *Path creation* refers to emergence of new development trajectories in a region leading to new industrial sectors and industries through diversification, branching or inward investment. (MacKinnon et al 2018). Regarding the concept of path creation, Grillitch et al. (2018) differ between industries that only are new to the region and industries that also are new to the world. The former is called path importation, i.e. setting up of an established industry that is new to the region. The latter is related to the emergence of an entirely new industry based on radically new technologies and scientific discoveries.

2.3.4. Industry paths and regional innovation system

A regional innovation system (RIS) consist of a knowledge exploitation and application subsystem (firms, organizations, etc.) and a knowledge generation and exploration subsystem (R&D institutions, mediating organizations, etc.). In addition, a RIS includes different mechanisms that stimulate linkages and collaboration between the subsystems (Njøs and Jakobsen 2017). Each RIS will have multiple industries that are on different development paths (extension, exhaustion, renewal, creation). The RIS has significant impact on the industry paths in the region and Isaksen et al (2017) argue that for regional path development to occur, the institutions and the entrepreneurs of the RIS needs to change or else a stale reinforced lock-in situation may occur.

Regions can also hinder innovation by failing to provide the necessary environment, so failures to innovate in a region can thus be looked at from a RIS perspective. Klein Woolthuis et al (2005) identified four system failures: *capability failures*, which is tied to the lack of competence of the industry; *coordination failures*, where industry knowledge sharing is either too prevalent or lacking; *institutional failures*, which is the hindrance of innovation through regulation, laws and other informal rules; *infrastructural failures*, that encompasses the systems and infrastructure that is needed to perform business activities.

RIS-barriers as mentioned above is discussed in Isaksen (2018) as related to path dynamics as actors may be lacking knowledge or competence for new industries to emerge, the network is too close for new knowledge to be acquired, the regulations and are traditional and hindering and physical infrastructure for emerging industries is not developed.

2.4. Challenges for the EEG-perspective

Agglomeration economies and geographical proximity for innovation and industry dynamics are concepts that has long been pointed as important by contributions through EEG where the local knowledge, routines, capabilities and institutions are highlighted for regional linkages for an industry (Bauer & Fuenfschilling, 2019). However, much of the work in EEG has emphasized the *regional* level when discussing the development of industry paths. Recently, this has been criticized in several contributions. Main drivers for development are not only the knowledge and networks of firms, entrepreneurs, and institutions in the region, but also their extra-regional linkages and other exogenous-to-the-region processes (markets trends, technology development etc.) (Isaksen and Jakobsen 2016, Mackinnon et al 2018).

This discussion on regional versus non-regional resources and the importance of geographical embeddedness, also echoes earlier contributions within economic geography arguing that some industries can be *footloose* (Alonso 1964). This is defined as an industry of which transport costs are relatively unimportant. To define an industry as footloose, Alonso (1964) identified three mechanisms: (1) decline of the price of transport units, (2) technological change driving weight of raw material down and (3) the complexity of the final product making the value of transport inputs relatively small. (Allen & Stone, 1992). While this transport centric definition is narrow, Allen & Stone (1992) also discuss the importance of agglomeration economies, communication and the absence of localized labor advantages as drivers for footloose-ness. The non-transport-oriented approach to footloose-ness thus defines a firm as footloose if it is independent by region and can be transferred to a new region as the fixed costs of goods are geographically independent and not raw material dependent, and can take advantage of communication and agglomeration to increase output (Allen & Stone, 1992).

The ongoing globalization has also made it possible to disperse economic activities to multiple geographical locations, and firms and industries are increasingly being multi-scalar localized. It has also been shown that emerging technological niches have global dimensions and the innovations is an international process (Bauer & Fuenfschilling, 2019). Regional linkages are typically affiliated institutions, domestic markets, professional reputation, and has a historical accumulation that affect the industry in its present state, while the development of more multi-scalar industries are affected by lowering production costs, movement of worker skills across borders, and faster distribution across distance of new research and technologies. (Yoon, 2015).

3. Materials & Methods

This chapter will give the reader an understanding of the data and data collection methods used in this master thesis. The choice of research design, methodology, subjects and criticism of said choices are focus areas of this chapter.

3.1 Research Design

Research design is the organization of research methods and procedures needed to produce reliable and replicable science, where the empiri is matched to the research question and conclusion. There are several possible research designs such as exploratory, descriptive and causal, depending on the amount of prior research on the variables in the chosen research question. Both descriptive and causal research designs depend on established knowledge while an exploratory research design is a tool that is used to uncover basic causal and is often used as an initial entry point to new fields. In this particular master thesis, the exploratory design was chosen as no prior research has been done on the industrial connection between the subject industries. The primary goal of an exploratory design is to uncover phenomenon and understand it. Drawing final conclusions based on an exploratory design should be done with caution.

3.1.1 Case studies

Cast studies are a type of empirical enquiry that aims to investigate a phenomenon in depth, a "case" in the real world to understand the boundaries between the phenomenon and its context (Yin, 2014).

The strength of case study methods are where statistical studies are weak, and George and Bennett (2005) identifies four advantages of case study methods; 1) Potential for high conceptual validity through measuring indicators that best represent what the researcher intends to study, 2) strong procedures for producing new hypothesis through identification of new variables, 3) their usefulness for investigating causal mechanisms in individual cases and 4) capacity for addressing casual complexity.

Weaknesses in case studies include case selection bias, where the subjects are self-selected or a conscious or unconscious selection by the researcher for a particular outcome, with the related issue of a researchers' foreknowledge of the values and variables in a case. Another weakness is that that case studies can only make tentative conclusions on the strength of a variable on a particular outcome, and finally case studies are not representative for a certain population and thus a researcher should not make such claims (George and Bennett 2005). Case studies can be done either as single- or multiple- case studies. This master thesis is a multiple-case study. It compares two different cases, the salmon industry path in the Bergen region and the emerging cell-based seafood industry. The intention is to uncover the potential for renewal of the seafood sector in the Bergen region through cell-based seafood production. In order to investigate this potential for renewal, we selected one dominant path (salmon industry) representing continuation or extension and one path representing change or renewal (cell-based seafood production) as our case studies.

3.1.2. Research Objective

The objective of a case study is to build on established theory, to clearly reason and focus on the research problems and how they relate to the current state of knowledge and theory. George and Bennett (2005) identifies six different kinds of theory building research objectives; 1)

Atheoretical/configurative idiographic case studies that do not contribute directly to theory but provide descriptions for further studies, 2) *disciplined configurative* case studies use established theories to explain a case, 3) *heuristic* case studies tries to identify new variables, hypotheses, causal mechanisms and causal paths where outlier cases may be particularly useful, 4) *theory testing* case studies that assess the validity and scope conditions of single or competing theories, 5) *plausibility probes* are studies on untested theories and hypothesis to determine if more laborious testing is needed, and 6) "*Building Block*" studies identify common patterns or a particular type or subtype of a phenomenon.

The chosen theoretical framework of evolutionary economic geography is rigorous and provide a solid foundation for addressing the research questions. The specific subjects however have not been comparatively studied in innovation theory before and as such there are certain elements of disciplined configurative, heuristic and 'building block' case studies involved in this master thesis as I both wish to use established theory and to identify new variables, causal mechanisms and common patterns when investigating the two selected cases.

3.2 Data collection methods and sources

I have employed exploratory research techniques such as secondary research, informal qualitative approaches and formal qualitative approaches to build a comprehensive data pool. By utilizing multiple data collection methods, I also increase the validity of the data by having the possibility to triangulate data.

Secondary research data collected for this thesis include scientific articles such as review articles on aquaculture and clean meat but also news coverage and a white paper on seafood clean meat. Media, in the form of news articles online and posts on social media such as LinkedIn was monitored for news on both industries during the data collection period which took place in Q1-Q2 2019 to give the author a good understanding of the status of both industries.

Semi-structured in-depth interviews were chosen as the main data collection method. Most of these interviews were executed in person, except one which had to be rescheduled into a conference call due to an unforeseen personal event. Interviews were done in San Francisco where the majority of the clean meat industry interviews were undertaken, while the aquaculture interviews were undertaken in Bergen, Norway. The audio from the interviews were recorded after agreement from the participant, and later transcribed by a combination of automation software and manual transcription by the author.

Participatory study is a data collection method that naturally occurred as the author has interacted with both industries closely while collecting data for the master thesis but also from a personal involvement in the aquaculture industry and the clean meat industry. While visiting San Francisco the author lived with one of the subjects for a week while also interacting closely with other subjects involved in the clean meat industry. For the last couple of years, the author has also been involved in the aquaculture industry as a startup and also worked for one of the subject companies. This involvement has resulted in substantial data collection in the form of informal conversations with a wide range of stakeholders that can be triangulated with the claims made by the interview subjects.

3.3 Data collection subjects and organizations

The informants for the semi-structure in-depth interviews are incorporated in either Norway or the United States of America with the majority having their headquarters in either Bergen, Norway for the salmon industry and San Francisco, USA for the clean meat industry. The interviews were performed with people either in the CEO position or at least in the management group to assure representative views. It should be noted that since the aquaculture industry is not particularly familiar with the clean meat industry, some of the interviewees expressed personal opinions as the organization as a whole has no established views. Firms were selected for their involvement in innovative practices such as supporting innovation through information, finance or performing innovative processes in house. Where possible similar firms were chosen in both industries to increase the validity of the data, and thus I have interviewed one interest organization in each industry and one business accelerator in each industry.

Informant Pseudonym	HQ Location	# Employees	Type of Organization	Focus	Interview Date
Finless Foods Informant	San Francisco	11	Startup	Cell-based seafood	18.02.2019
New Age Meats Informant	San Francisco	6	Startup	Cell-based meat	21.02.2019
Mission Barns Informant	San Francisco	10	Startup	Cell-based fat	20.02.2019
IndieBio Informant	San Francisco	4	Business accelerator	Biotechnology startups	18.02.2019
Hatch Informant	Bergen	6	Business accelerator	Aquaculture startups	28.03.2019
GFI Informant	San Francisco	84	Network organization	Innovation in plant based- and clean meat	12.03.2019
NCE Seafood Informant	Bergen	4	Network organization	Innovation in salmon aquaculture	27.03.2019
Grieg Seafood Informant	Bergen	780	Established firm	Salmon production	01.03.2019
Manolin Informant	Bergen	3	Startup	Software for salmon production	09.04.2019

Table 1. "*Overview of informants and their organizational affiliation*"

3.4 Validity and reliability

Reliability is an indication of how sound the research is, and if the collected data truly represent the studied phenomenon. By achieving high reliability, reproduction of the study will yield similar conclusions. When conducting this thesis, data has been stored to make reproducible results possible. I would like to add one caveat to the reliability of this study. Due to the recent GDPR laws in Europe, I have opted to store the data until the end of the year of 2019, which means that reproduction of the study can be done within a limited timeframe.

Validity is a measure of how accurately the research findings represent the studied phenomenon. In this master thesis I conduct qualitative oriented case studies of two selected industry paths. Such studies have a potential for high conceptual validity, since a qualitative oriented approach gives me deep insight into the key dimensions of the study objects (George and Bennett 2005). Generalization of the found phenomenon is also an important criterion for data with high validity, and as mentioned in 3.1 I am using multiple case studies for replication logic that strengthen the validity. However, this is not a generalization to some defined population that has been sample. Instead, qualitative case studies can contribute toward theory discussion and theory development (George and Bennett 2005). This is what Yin (2005) categorize as analytical generalization. In this master thesis I intend to discuss to which extend my empirical findings can confirm or nuance the ideas of EEG (see 9.2).

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3.5 Limitations and criticism of chosen method

The author has been employed by two out of the nine subject firms for periods ranging from a couple of weeks to 18 months and has been working closely with two of the other subjects for between 6 months and one year. Due to the author's involvement in the industries, the results cannot be said to be truly objective. While it can be argued that epistemologically, no study can be truly objective as the author is subjectively drawing conclusions based on the collected data, the choice of in person interviews with subjects that the author has a previous relation to and participatory study of both industries does give the collected a certain bias. There has also been challenging to incorporate the myriad of informal interviews that the author, who is heavily involved in both industries, has gone through over the last year for personal reasons.

4. Introduction to salmon aquaculture and cell-based seafood

This chapter will give the reader an introduction to the two subject industries, salmon aquaculture and cell-based seafood, through based on secondary sources such as scientific literature, company information and white papers. The first section, *4.1 Salmon Aquaculture Overview*, is an overview section about the salmon farming industry in Norway and the second section *4.2 Cell-based seafood overview*, is an overview section about the cell-based seafood industry.

4.1 Salmon Aquaculture Overview

4.1.1 What is salmon farming

Several different salmonid species are incorporated under the common name “salmon”, such as Atlantic salmon, pacific salmon and Coho salmon, and several salmonid species are also incorporated under the common name “trout” such as Brown trout and Rainbow trout. In Norway, salmon refers to the species Atlantic salmon (*S. salar*), and trout to the species Rainbow trout (*O. Mykiss*), which are the only two salmon and trout species industrially farmed in this region. Due to their very similar end products and farming methods, I will refer to salmon and trout farming as salmon farming in the rest of this thesis.

Salmon farming is dependent on coastal areas with some key environmental conditions such as that the temperature should vary between zero and 20 degrees while staying in the optimal range of 8-14 for as long as possible. An archipelago or a fjord geography is needed since it is shielded enough from the more exposed conditions while at the same time providing ample oxygen rich water with a slight current. There is also a dependence on the local political willingness to permit salmon farming and regulate the industry, and thus most areas where salmon farming is permitted use a license system. Due to these restrictions, farmed salmon is only produced in Norway, Chile, Scotland, the Faroe Islands, Ireland, Iceland, Canada, USA, Tasmania and New Zealand (MOWI, 2018).

Salmonids has a complex anadromous lifecycle and live the first juvenile stages of their life in freshwater rivers and will migrate out to sea after a physiological transformation called smoltification where they adapt for a life in sea water. After the salmonids have grown into adults out at sea, they will return to the rivers to spawn after going through a maturation metamorphosis to once again adapt to freshwater. This complex life cycle is reflected in the salmon farming by the necessity to keep farmed salmon in both freshwater and seawater during its life. The salmon will hatch in land-based facilities where they are reared until they smoltify, whereas they then are transferred to sea cages to grow to slaughter weight of about 3-5 kg. While the majority of the salmon is slaughtered, some separate broodstock lines are kept to select for favorable traits such as growth and fillet color.

Salmonids constitute approximately 4.2% of the total seafood global seafood production (MOWI, 2018). In Norwegian aquaculture Atlantic salmon is overwhelmingly the most farmed species both in terms of value and biomass with a production of 1,15 million tonnes at an export value of 64 billion NOK value in 2017 compared to 2700 tonnes of other marine species at a 228 million NOK value in 2017 (Norwegian Directorate of Fisheries, 2018). These 1,2 million tonnes constitute more than half of the world's total supply of Atlantic salmon, which was around 2.2 million tonnes in 2017. These 2.2 million tonnes of global salmon production can be compared to the significantly higher biomass production of tilapia, 4.2 million tonnes in 2016 (FAO, 2018), and shrimp, 5.4 million tonnes in 2016 (FAO 2018). While salmon may not be the most farmed species around the world in terms of biomass, the monetary value of the salmon is significant, which means that Norway was one of the leading exporters of fish in 2016, with an export value of 10.8m USD, second only to China, at 20,1m USD.

In short, salmon farming encompasses several species of salmonids where the Atlantic salmon is the dominant species, and while the salmon is not the largest in terms of biomass, it is of significant value, and thus its' complex life cycle has been worth taming for Norway where salmon farming is one of the country's leading industries.

4.1.2 Industry History

The industry has its roots in the hands-on experimentation and development by the early entrepreneurs in 1960 at the western coast of Norway (MOWI 2018). One of the defining moments of aquaculture in Norway was the development of the open pen farms for use in marine waters in 1969, which allowed for significant reduced costs and more efficient operation of larger farms. Historically many small firms made up the salmon farming industry due to regulations that one owner could only own one farm, but after this government abolished this law in 1990 the trend has been towards consolidation in all regions (PwC, 2018).

Salmon farming has been combating diseases since the birth of the industry, and during the 1980's there were developments in vaccines that rendered the use of antibiotics almost obsolete (Hjeltnes et al 2019). Research efforts have historically been concentrated on the areas where the most resources have been used, and thus heavy research and optimization during the industry history has continuously on feed optimization. In the early phases of the industry the feed used was moist instead of dry pellets and contained marine protein in the 60% and fat at 10%. The feed composition numbers are now under 15% for marine protein and 30% in fat content due to an increased amount of content from vegetable sources (MOWI, 2018).

In 2015 the Norwegian parliament supported a white paper by the government on how to regulate the industry to maintain environmental sustainability while maximizing value creation through the implementation of a predictable system that relies on the salmon lice level of the farms as the indicator of the industry status. The system applies to open net pen farming which is the dominant production form and is the system that regulates the industry today (Ministry of trade, Industry and Fisheries, 2015). One of the driving forces for the development of new farming technology has been the Norwegian state of fisheries and the policy that new licenses was to be earned by applying though development licenses, where significant innovation and technological expertise was needed to secure a license. The applications closed in 2017 and garnered 104 innovative new concepts where around 10 of these concepts have been granted licenses (Fiskeridirektoratet, 2018).

4.1.3 Industry status

Salmon farming has been an economic success story for Norway, and there has been a rapid value growth in the sector. The last 15 years, the value creation from the seafood industry has almost doubled due to increased volumes from aquaculture, sales prices and wider economic impacts (Fredheim & Reve, 2018). While the value creation has doubled, there have been almost no change production volumes over the last five years, with a total salmon production of approximately 1,3 million tonnes annually (Statistics Norway, 2019).

The dominance of these specific species has led to an institutional specialization that perforates all aspects of governance, research and industry in Norwegian aquaculture. The Norwegian seafood complex consist of interest organizations, salmon farmers, technology suppliers, fishing vessels, startup accelerators and incubators, investors, supporting firms, research institutions, investors and a regulatory framework (Aarseth & Jakobsen 2015) where most of these entities are present in Bergen, Norway which is considered the capital of aquaculture (UiB & IMR, 2018).

With an EBITDA margin close to 40%, the salmon farmers are currently very profitable (EY, 2018). The farmers' operating profit of almost 20 NOK per kilo produced salmon is mainly due to the increased sales prices for salmon, which increased from 26 NOK per kilo in 2008 to 61 NOK per kilo in 2017. The salmon price is expected to continue in the future due to a growing population, growing middle class, depleted fisheries, healthy product and resource efficient production (MOWI, 2018). While the farmers are profitable, the increased costs in production, mainly driven by sea lice and disease, means that profitability is lower than the most profitable year of all time that was 2010 (EY, 2018). The salmon farmers receive the lion's share of the industries total profits, and the supplying industries were down at 3% EBITDA.

In Norway a salmon farming license awarded by governmental institutions is needed to farm salmon for each locality or facility that is established on land or at sea. Sea water licenses are limited, and 1015 such licenses are awarded as of 2017 (MOWI, 2018). Open pen farming of salmon in Norway requires a license to operate. These licenses have recently been auctioned out, and in June 2018, the Norwegian Directorate of Fisheries had an auctioning round where the costs of the licenses were reported to be from 132 NOK/kg to 252 NOK/kg, which is an increase from the 2014 auction prices where the costs were closer to 75 NOK/kg. The Norwegian coast is divided in 13 production areas, and the maximum produced salmon in each region is dictated by the level of sea lice present in those areas. The sea lice level is calculated based on the amount of mature female sea lice present on the fish in the cages. A selection of fish is counted every week by the farmers to determine the locality lice level and these numbers are compiled into a production zone level. This system is called the “traffic light system” and in 2018, 8 out of the 13 areas had low enough lice numbers that their production zones were green, and thus in theory are permitted to grow their biomass 6% every second year (MOWI, 2018).

Due to the profitability of the sector and barriers to entry through limited natural salmon farming areas and the restrictive licensing system, other more expensive forms of production have started appearing, such as the 90000 tonne land-based facility owned by Atlantic Sapphire that is under construction, which is only one of the many new projects to produce salmon in land-based facilities.

Most of the salmon produced in Norway, over 80% in 2017, is exported whole to be further processed in other countries due to operational reasons such as the high cost of processing in Norway, increased flexibility when processing close to the markets and transport during rigor-mortis when the fillets are unprocessable. There have also been high customs taxes to Europe on processed salmon products which has made product development within Norway challenging (PWC 2019).

One way to increase the value creation from seafood in Norway is to better utilize the waste coming from the industry in the country. Norwegian salmon is often being consumed fresh in parts of the world that requires a transit time low enough not to spoil the product. Air transport is often used to fly fresh salmon to Asia for example, but this practice increases the otherwise stellar salmon carbon footprint from around 2kg per kilo to 15 kilo per kilo. While land-based salmon has a higher carbon footprint than traditional open pen farming (sauce), it is seen as an alternative due to the reduction of air miles if the salmon is produced near the market (EY, 2018).

Fish feed represents half of the total production costs of salmon, and thus has been subject of optimization and transformed over the course of the industrial history. The goal of feeding is to grow a healthy fish fast and at the lowest possible cost thus much of the production is highly specialized and advanced (MOWI, 2018). Salmon are carnivores and require feed high in protein and fat while low in carbohydrates. Shortages of marine materials as ingredients in the fish feed, most notably fish meal and fish oil, has forced the introduction of new feed components. Soy meal which has long been used in land-based animal farming, is now also being used in fish feed to cover the protein need of the fish. Today about 30% of the feed is of marine origin, the rest, 70% is vegetable derivatives (Laksefakta, 2019). Good fish health is vital for producing salmon of high quality, and thus fish health is a significant focus for the industry. Nowadays, under 1 tonne of antibiotics is used for the whole Norwegian fish farming industry which makes it one of the lowest antibiotic contents in the world (Hjeltnes et al. 2019). Viral diseases have been a harder problem to solve, and diseases such as PD, heat and skeletal muscle inflammation (HSMI), infectious salmon anemia (ISA) are widespread and are a source of significant biomass loss in farming today. While the viral diseases are challenging, the sea lice, a family of crustacean parasites, is considered the largest problem for the Norwegian salmon farming industry (Hjeltnes et al. 2019). Traditionally hydrogen peroxide and chitin synthesis inhibitors such as teflubenzuron have been used to combat the lice, but recent scientific reports have increasingly questioned the use of these medicinal treatments due to its impact on wild marine crustaceans such as shrimp and lobster (Samuelsen et al. 2015).

Strict regulations together with environmental impact concerns have forced the development of alternative lice treatments which in turn has helped making medicinal treatments rarer. While the use of cleaner fish, wrasse and lumpfish, is used to keep the sea-lice levels at bay, they are not effective enough to render delousing unnecessary. Today mechanical delousing methods are dominating, where the salmon is subjected to washing or warm water treatment, but these methods are also coming under scrutiny after reports that the salmon suffer long term damages after treatments though physical damages and an impaired immune system (Hjeltnes et al. 2019).

4.1.4 Industry future

In his annual statement to investors Lerøy Group CEO, Henning Beltestad notes that the company, which is the second leading producer of farmed salmon in the world, is expecting that the global annual growth of 5-6% per year will continue in the years to come and that the salmon price of 60 NOK/kg is acceptable for consumers and thus should remain relatively stable (Lerøy Group, 2019).

While the present looks promising, there are still concerns of how the sector will grow in the future. One of the biggest challenges of the Norwegian salmon industry today will be to grow the produced volumes in a sustainable fashion. There is a governmental pressure to increase taxation and reduce the biological impact the industry has on the environment. The growth of salmon farming in Norway is regulated by a system that is based on the amount of salmon lice present at the sites. The reduction of salmon lice has been the most pressing concern for the industry over the last few years and since no solutions have been found so far, value growth in the sector can be assumed to come from other places that pure biomass growth. (PWC, 2019).

On the feed side the shortage of marine materials has forced the industry to innovate on novel feed sources, and there are many projects on the use of insects, algae for fish feed and genetically modified plants for omega-3 production while novel treatments and preventive measures in the war against sea lice is continuously being developed but there are currently no single solution to this complex issue.

land-based salmon farming is becoming a continuously sounder investment as it de-couples the farming from the limited areas that is suitable for salmon farming and also provides a system with better control of what is released into the surrounding. The costs associated with land-based farming is decreasing while the costs with open net pen farming is increasing, which means that the production price gap is increasingly getting smaller, which at some point theoretically could render the open pen farming method more expensive than land-based farming (EY, 2019).

In their Norwegian Aquaculture Analysis 2018 report, EY had identified land-based grow out projects of more than 350,000 tonnes in 2022 and onward, which would be 13% of the expected world production in 2020 (EY 2019).

4.2 Cell-based Seafood Overview

4.2.1 What is Cell-based Seafood?

Cell-based seafood is a section of the clean meat or cell-based meat industry that aims to produce seafood, through similar processes. During this chapter it is necessary to analyze cell-based seafood through the umbrella nomenclature clean meat and cell-based meat as much of the cell-based seafood is identical to cell-based meat.

Clean meat, cultured meat, cellular agriculture, in-vitro meat, laboratory grown meat and cell-based meat are all different names for the same industry, which is an emerging biotechnology field that promises a new disruptive way of producing muscle tissue for food without animal involvement (Stephens, 2018). The field is based on tissue-engineering and includes cultured meat and leather systems in which cells or cell lines taken from living animals are tissue engineered in an effort to produce useable tissue with minimal quantities of animal tissue input compared to livestock methods in which the cells themselves form the product. Starting material, i.e. the cells, can be taken from an animal using a biopsy procedure (Post, 2014). There are exciting opportunities for academic researchers and industrial partners to advance this novel field as there are still many challenges that are unsolved in practice but possible in theory, but the main challenges will reside in scale-up and cost reduction (Specht, 2018).

On the cell-based seafood side, in a white paper titled “An ocean of opportunity”, the Good Food Institute has created an overview of the opportunities and advancements in developing plant-based and cell-based seafood and specific approaches on how to capitalize on these opportunities (The Good Food Institute, 2018).

Because of the similarities in cell production methods and fundamental biological requirements of animal cells between species, most cross industry innovation is likely to come from progress made in a sub-industry of clean meat as co-evolution, and thus progress made in bovine based clean meat has high transferability to cell-based fish (Good Food Institute, 2018). There are however unique challenges and advantages for clean meat seafood. Marine species are not routinely cultured at most research labs which is reflected by the absence of optimized protocols and the low number of fish cell lines available in cell-line databases. From the 100,000 cell lines available in the Cellosaurus, only 558 are fish cell lines and from those only nine are cell lines isolated from fish muscle cells, none which are myoblastic muscle cells (Rubio et al. 2018).

In a preprint from 2018 by Rubio et al. titled: "Cell-based fish: a novel approach to seafood production and an opportunity for cellular agriculture" the author argues 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. The author states 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 such as chitosan, makes for a promising cell-based seafood production. However, the literature is sparse on marine animals, especially crustaceans and bivalves (Rubio et al. 2018).

While there are plenty of technical advantages for cell-based seafood, there is also an appeal to pursue cell-based seafood from a business standpoint. Many types of seafood are traded at high prices, making low volume product possible. Seafood is also more likely to be consumed raw or minimally cooked which may cause food-borne illnesses due to the variety of bacteria, viruses and parasites that marine animals carry. The sterile condition and aseptic cultivation of cell-based seafood should not only make it contaminant free; it may also dramatically increase the shelf life (The Good Food Institute, 2018).

4.2.2 Industry History

In the 1930's essay titled "50 Years Hence", Winston Churchill envisioned a future where meat could be grown in vitro: "We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium." (Reuters, 2018). Among the earliest examples of tissue engineering we find Alexis Carrel who in 1913 transplanted chicken heart tissue onto a continuously irrigated nutrient medium on a glass dish. The explant doubled every 24 hours and continued to do so for over 30 years (Benjaminson, 2002). In 2002, Benjaminson et al. investigated the use of tissue engineering to feed astronauts with fresh animal meat during long voyages through a NASA-funded project where the result were small quantities of carp muscle tissue that was assessed for palatability. In 2005 Edelman et al wrote a commentary in the journal Tissue Engineering on the topic in-vitro cultured meat production highlighting the opportunities and challenges of cultured meat. The commentary concluded that scaffolded cultured meat appears technically feasible and that biological structures required for locomotion and reproduction would not be needed (Edelman 2005). In the same year, the Dutch government funded two three-year PhD projects to culture porcine cells, develop algae based medium and use electrical and chemical stimulus to induce mouse cell growth. This Dutch body of research led to one of the most iconic moments in clean meat history, when in 2013 when the world's first cell cultured burger was cooked and eaten at London press conference as part of a research project lead by professor Mark Post of Maastricht University, backed by Google co-founder Sergey Brin (Stephens, 2018). This high-profile event led to a flurry of activity and multiple start-up companies entering the space and garnered the interest from large traditional protein corporations such as Tyson Foods and Cargill who subsequently have invested into the industry and thus strengthening the validity of the field. There has been significant growth in interest in clean meat over the last year with multiple emerging startups and large investments going into the industry with large well-respected media channels such as Nature covering the progress (Nature, 2019).

4.2.3 Industry status

Currently multiple startups spread around the world that are racing to be first to market, as there are still no clean meat products available as of Q1 2019. In a review paper from 2018, Stephens et al mentions the companies Mosa Meats, Memphis Meats, JUST, Super Meat, Modern Meadow and Finless Foods as leading the field but much of the technical work in the field is conducted within these startup companies, which are selective with the information they make publicly available, and thus makes it difficult to know the exact industry status (Stephens, 2018).

From the initial research by Dr. Mark Post's research group from Maastricht University, a spin-off company called Mosa Meats has emerged which is focused on bovine meat. One of the startups that have raised most funding is Memphis Meats, which came out of the biotech accelerator IndieBio in 2015 and is claiming to have produced both the world's first cell-based meatball and cell-based poultry. In Israel, Super Meat is working on cell-based chicken and has a patent pending on hybrid cell-based plant-based food (Savir, Friedman & Barak 2018) while Aleph Farms revealed the first lab grown steak in 2018 which was covered by the Guardian (The Guardian, 2018). In late 2018 the company JUST, formerly Hampton Creek, which is producing plant-based substitute products announced a collaboration with a Japanese beef producer to develop cell-based Wagyu beef products, after previous having been focused on cell-based chicken nuggets (Food Navigator USA, 2018).

On the seafood side Finless Foods are working on tuna showcased the first cell-based fish product prototype in 2017 (The Guardian, 2017), while Shiok Meats presented the first cell-based crustacean prototype early 2019 and are working on shrimp and crab (Techcrunch, 2019). The above mentioned companies showcase the trend that research decisions on species selection in the cell-based field has largely been driven by market size and environmental impact and not necessarily by the suitability of the cells for in vitro cultivation (Rubio et al 2018), but as the field is maturing, the technical feasibility of the cells are coming into focus which could lead to cell-based products from exotic species being developed.

On the regulatory status of the industry, there are progress on how to govern the industry effectively, but there are still challenges to be solved. In a press release by the U.S. Department of Agriculture (USDA) on the 16th of November 2018 it was announced that clean meat will be regulated under the same laws that govern traditional meat. The regulatory bodies that will oversee the production of livestock and poultry products will be a joint collaboration between the Federal Drug Administration (FDA) and the USDA (USDA, 2018). It should be noted that this press release does not mention seafood. In Norway the authorities responsible for food safety is the Norwegian Food Safety Authority (NFSA). This body is generally adapting laws set by the European Food Safety Authority (EFSA), where the laws for how clean meat should be regulated are clear and specifically fall under the novel food category where the companies have 18 months to prove that the product is safe to consume (EFSA, 2018).

The state of consumer acceptance is keenly monitored by the industry due to the disruptive nature of cell-based protein production. Studying the impact of new knowledge on perception was the key focus a Dutch study, this time using psychological experiments with 506 responses, which found different stimuli information altered individuals' considered opinions of cultured meat, although it did not affect their instinctive positive or negative response (Bekker, Fischer, Tobi, & van Trijp, 2017) In a 2018 review paper by Stephens, other cellular agriculture products may reach market first and sway public opinion and thus alter the public perception of clean meat and the novelty and ambiguity of the status of cultured meat means that a shift in opinion is likely. Thus, the consumer acceptance studies done may not be representative of the market when the products are launched (Stephens 2018). Consumer acceptance is also tied to local culture and religious beliefs. Mohammad Naquib Hamdan concludes in a 2017 paper that cultured meat acceptance by the Muslim world is dependent on it being compliant with Islamic law. The author states that compliance will be met if 1) cells are derived from halal slaughtered animals and 2) animal serum for culturing should be avoided unless it can be proved that the serum will not make the meat unclean.

Clean meat is a rapidly emerging field that has its technological roots in tissue engineering and physiological research. Critical technologies needed to bring clean meat to market will have to be adapted from innovations in other cell culture heavy industries such as cell-based therapies, regenerative medicine and antibody protein therapeutics (Specht, 2018). While there is cross-industry potential with the above industries, the clean meat industry will however have to produce cells in a scale that is orders of magnitude higher than that of the medical sector to match the output of the meat production industry, and thus have a unique set of challenges in technological development. These challenges are being solved from multiple stakeholders and a number of tastings, prototypes and demonstrations over the last couple of years show that there are no fundamental technological flaws to bring clean meat to market (Specht, 2018).

4.2.4 Industry Future

Much of the industry future relies on handling the technological challenges, and the most important technical challenges for the industry today has been categorized as cell-line development, cell-growth medium, scaffolding and bioreactors by Specht, 2018:

1) *Cell-line development* is essential for a continuous stable supply of cells that can be developed with increased robustness, metabolic efficiency, speed of muscle derivation and other improvements through selection and/or CRISPR (Specht, 2018). There are two starting points of cellular agriculture, primary cells or cell lines. The primary cells are biopsied from mature tissue of the animal while cell lines are either established by inducing immortality and indefinite proliferation through an induction or my selecting cells with spontaneous mutations resulting in these traits (Eva et al., 2014). When selecting cell candidates for cell-lines a cell that doubles in days, is genetically stable for at least 50 divisions is desirable (van der Weele, 2014). Since robust stem-cell lines are vital for large-scale clean meat production, in early 2019 the non-profit organization the Good Food Institute has awarded an Oslo based research group a research grant for the project "to develop a pluripotent stem cell bank (University of Oslo, 2019)

2) *Cell-growth medium* act as a feed source and provide nutrients, hormones and growth factors Today FBS is one of the key components in cell mediums and also one of the most ethically questionable due to its animal origin. A fully defined serum free and animal origin free medium at a reasonable price is needed to bring competitive cell-based products to market. Van der Weele wrote in 2014 that growth medium is the biggest cost driver and a growth medium price of €1000 per m3 would give a cost price of €391/kg, he further argues that a growth medium price of €1 per liter would bring the price of clean meat down to the price of conventional minced meat (Wan der Weele, 2014).

3) *Scaffolding* is the process of structuring the cells in 3D space and provides the basis for thick-tissue products, such as steak. Without scaffolding only unstructured products such as ground meat is possible which severely limits the potential of the industry. Techniques to achieve successful scaffolds are derived mainly from tissue engineering and requires co-culture of multiple cell types and complex media perfusion transport systems (Specht, 2018). Scaffolds have traditionally been derived from animal origins but new research on food safe plant derived polymers has shown that materials such as alginate may be an ideal 3D scaffold for cell culture (Andersen, 2015).

4) *Bioreactors* act as the closed systems where the cells proliferate and mature. To acquire one kilo of muscle cells the total cells needed would be approximately 8x1012 cell, which would mean a bioreactor in the order of 5000 liters would be needed when using traditional stirred tank technology, and while this volume is commonplace in established bioprocessing it is yet unproven in tissue engineering (Stephens, 2018). New research in bioreactor design fueled by bio-pharmaceutical needs for high density Chinese hamster ovary culture has increased the maximum attainable cell densities to above 1×10^8 cells/ml by using alternating and tangential flow filtration technologies (Clincke et al 2013) which will be crucial for cost effective large-scale clean meat production. Stephens 2018 argues that while cell expansion will be a challenge at scale, the greater challenge will likely be muscle cell differentiation of which no large-scale methods have been developed. Lastly, there is a need for automation in cell manufacturing to reduce contamination risk and variability from human handling as well as effectivizes the speed and cost for processes such as harvesting at scale (Specht, 2018).

5. Salmon aquaculture analysis

In this chapter, I will analyze the first research question RQ1: “*What characterizes the salmon industry path in the Bergen region*”. Seafood, and especially salmon aquaculture is an important industry for Norway and Bergen is a region where much of the salmon farming industry is clustered. This chapter is based on interviews with four representants from different parts of the Bergen salmon farming industry to understand the characteristics of this industry path. The firms are: 1) *Grieg Seafood* to represent the views of a salmon corporate, 2) *NCE Seafood* to represent the views of a salmon interest organization, 3) *Hatch* to represent the views of an aquaculture startup business accelerator and 4) *Manolin* to represent the views of an early stage startup in the salmon farming industry.

An industry path is characterized by a combination of continuation and change (Fløysand and Jakobsen 2016). In our analysis of the characteristics of the salmon industry path in the Bergen region I will especially investigate processes of change or renewal of the industry path. Renewal can take place through the introduction of technological innovation, or process innovation, among established firms, i.e. new ways of organizing the production. It can be through new entrants to the industry, or it can be through the introduction of new products (see chapter 2 for more detail). I start the chapter with 5.1, which covers Bergen as the center of the salmon aquaculture industry, followed by 5.2 which covers R&D, technology and innovation among established firms in salmon farming, 5.3 is a chapter on new entrants to the industry, and 5.4 is a short chapter on new products in the industry, 5.5 covers the future of salmon farming and finally 5.6 is a summary of the salmon aquaculture analysis.

5.1. The aquaculture capital Bergen

Bergen has over the last years started to become increasingly recognized as the center for aquaculture, with several institutions such as the University of Bergen and the Institute of Marine Research establishing initiatives such as “Ocean City Bergen” which emphasizes the position of

Bergen as a world leading marine cluster, and the 13th largest city in the world measured on amount of marine scientific articles (UiB & IMR, 2018). 57 companies with salmon and trout production operate in the Bergen region, which is the largest number of companies in any county in Norway (Norwegian Directorate of Fisheries, 2018). In this thesis the concept of Bergen-region refer to Hordaland county. This is an area at the Western coast of Norway with approximately 520 000 inhabitants (SSB 2019). This aquaculture region has also started to attract newly established international companies to the region: *"[...] it's the center of aquaculture in the world. We needed a lot of help. We needed market access to the companies and Bergen, we saw as a hub of aquaculture activity. It's where business is conducted in this industry. And we believed that being a part of that ecosystem was very important."* (Manolin Informant).

5.2. Technology development and process innovation in salmon farming

Grieg Seafood, with its headquarters in Bergen, is one of the world's top salmon producers has a salmon production focused strategy where the goal in 2020 is to grow their Norwegian salmon production from 65,000 tonnes to 100,000 tonnes: *"We are very production-focused. Vi have a very concrete strategy towards 2020 to utilize our licenses to grow to 100,000 tonnes which is a considerable growth from the start of the period, from 65 to 100. This is the main focus."* (Grieg Seafood Informant).

Salmon farming is highly industrialized and technically advanced compared to other forms of aquaculture: "*Bergen is the head of Norway in Salmon. And then salmon also leads all of aquaculture in our mind."* (Manolin Informant). The focus of salmon farming is to produce salmon, and the product that the farmers are producing is predominantly whole salmon without any value-added processing: "*We're only producing whole fish today [...] We don't have value added processing (VAP)*" (Grieg Seafood informant).

The salmon farming industry is heavily focused on the day-to-day operations and often does not have internal resources set up to handle complex long-term innovation projects: *"We take the role of industry because the industry doesn't always appreciate being in the project. They are extremely operational, as you know, and they don't have the set-up to participate heavily in EU projects, or at least not many projects. However, they're very fond of the resources coming out*."

(NCE Seafood Informant). Much of the innovation is focused on increasing efficiency of the farms and there is a big push for automation: "[...]*in Norway, high labor cost, lack of labor at remote areas has pushed automation and robotics into the mix. I think you see other types of automations happening in other areas where those are not so much the challenges"* (Manolin Informant).

The last couple of years, many early stage companies have seen the potential of the salmon farming industry because it has been lagging behind in technological development: *"The digitalization we see in the industry today is far behind agriculture and other industries and it is a "gut-feeling" industry."* (Grieg Seafood Informant). Salmon farmers are however more advanced than other aquaculture sectors, and the farmers are seemingly more used to digital tools: "*when you go to an oyster farmer who has never seen technology before, just showing a table is showing a website is special and unique and something flashy and shiny and normal Norway, you have to come up with even more flashy, shiny or things because they're so accustomed to it."* (Manolin Informant).

NCE Seafood plays a central role in coordinating innovation and have recently launched an innovation platform to help match the innovations with the pains of the salmon producers with problem solutions and ideas from early stage companies. This initiative sprung out of a need to get more structure in the way the salmon producers get approached with new ideas, as they are often flooded and overwhelmed with options to purchase new solutions that they may or may not need: *"It's complicated and fractionated as it is now, so it's non-accessible for basically anybody and it doesn't help if I have this information in my head and somebody else has another fraction in their head, we need to get that up on a platform where you can see in the complete mosaic and people can actually find both pains, possibilities and money and make those work much more together."* (NCE Seafood Informant).

Hatch which is an accelerator, and thus is dependent on startups that can increase and "scale" to cover large parts of the market with their solutions are often looking for the next big thing in aquaculture, but they see that the farmers themselves are more interested in the incremental "medium term" trends to solve the issues that are at hand in the moment: *"everything that is basically in the trend of like medium term trends, I think that's going to get picked up. [...] But they are not these like really large-scale ambitions, long term ambitions and really disruptive concepts I would say.*" (Hatch Informant). While the innovation is incremental, and medium term trends it is still fast paced: *"[...] aquaculture is even more fast paced (than* *agriculture) in a sense because of the pressure from a sustainability and political argument because of the fact that the industry is so young they've had to move even faster"* (Manolin Informant).

There has not traditionally been much focus on the products themselves from the farmers, as the value chain is split up so that the export companies and processing is not necessarily handled by the same company that is producing the fish. Thus, the focus has also been to optimize production and the biological environment for the salmon: *"There has been a focus on reducing the (production) cost. So our innovation, so far focused around growing and keep good biology in the sea."* (Grieg Seafood Informant). Grieg seafood has a specific production strategy which is called "Post-smolt" which is a strategy utilized in the industry to reduce the time the salmon will spend in the sea phase. The idea behind the strategy is to keep the salmon on land as long as possible to optimize its robustness and size and then the time to grow from around 500g to 5 kilos will be short and thus the exposure to salmon lice is reduced: *"Post-smolt gives both better biology and shorter time at sea but also increased growth, and as new licenses is not being granted in the sea anymore."* (Grieg Seafood Informant). Grieg also has a strategy to be the leading salmon farming company when it comes to digitalization, as it is a way to increase the control in the industry and get better decision making with the help of a larger dataset: *"[...] more data to get better is what we believe, better decisions and more sustainability."* (Grieg Seafood Informant). There is an increased focus on digitalization and data in aquaculture which has attracted new companies such as Manolin, a company that was founded in the US and originally had a product in the oyster sector: "*We would have stayed in oysters if we thought oysters could lead the industry [...] in our definition lead was maturity of the industry"* (Manolin Informant).

NCE Seafood Innovation cluster has recently spearheaded an effort to increase the understanding of fish biology through development of new sensors but will also increase the knowledge base and continue to lead aquaculture as a "new generation" of sensors are being developed: "[...] *it's all about a new generation of sensorics and understanding the fish and how the fish reacts to its environment in terms of that increased knowledge in sensorics and making a feedback loop into added sensorics. Again, deepening our understanding of biology. So, it's this deep science*" (NCE Seafood Informant). Much of the need for sensors is coming from the salmon farmers and their digitization efforts, which in turn have been inspired by the oil industry: "*[...] (in the oil industry) when you saw that digitalization was possible, the decisions could be moved* *to the place where the best decision could be made*" (Grieg Seafood Informant). The digitalization brings a need of sensors but also software, which is an area that have attracted several startups that hope to contribute with new software systems: *"[...] we hope that software and data innovation can help. That's the purpose I guess, of innovation is to be able to drive down those costs to a point that it is a sustainable, stable in balanced market and we think that has a role to play in the world."* (Manolin Informant). Manolin is developing a software system to help manage the complex disease issues the industry is facing. The Industry is facing biological challenges, caused by pathogens: "*[...] there are several issues that will become, and are actually, a problem as we speak. Complicated kill syndrome, there is PD there is, there are others, the CMS, [...]"*. Grieg Seafood notes: "*[...]the biological challenges are different in each region*", which further complicates the picture, but the decidedly largest challenge today in Norwegian aquaculture is sea lice. These challenges will likely continue in the future as most of the focus is set on salmon lice, as the other diseases are not under the same focus: *"Since we are working so and so incredibly heavily with sea lice, we don't put the necessary focus on the others. So they will be waiting for us when we come out to sea lice tunnel, we won't see any light. We would just enter the next tunnel."* (NCE Seafood Informant). These biological challenges will most likely exist in other production systems as well, so a switch from open pen farming to closed systems will do little to address the pathogen load: "*Closing fish in a closed system might reduce the sea lice, but it might increase flavo-bacterium which actually are beautifully adapted to closed systems and what we call biofilms on on smooth surfaces. There you will have to increase the salmon intensity which will increase skin vulnerability, which will increase infection rate. So we might see major wound problems are we going to antibiotictize us out of that problem? No we can't."* (NCE Seafood Informant).

While aquaculture and salmon farming is mostly about caring for the fish and optimizing salmon production, there are some areas with innovation exchange with other industries: "*[...] what we can do through aquaculture is export knowledge about, for example, fish diseases, breeding programs, feed and some technology."* (NCE Seafood Informant).

The logistics of selling fresh fish is something that has led to opportunities for innovation in logistics, a field that is used for almost every other industry and thus has real cross industry innovation potential. Grieg seafood has been working on a sub-chilling process which is a way to minimize the ice that is used to cool the fillets during transport by chilling the fillets themselves in a way that is non-destructive to the quality of the meat: *"We have worked with freezing* *technology from Iceland [...] It is then 20% less ice which gives a lower CO2 footprint and better quality of the fish."* (Grieg Seafood Informant). There has been significant innovation to keep the salmon fresh over long transport distances: "*There is the cooling chain. Then we are really good on that. And that is something we need to help the third world to establish a lot of their food is spoiled because regretfully they are in a very hot areas and without cooling infrastructure. A lot of their production is going to be ruined before it enters the market.*" (NCE Seafood Informant).

"Salmon is a market in an industry that will not go anywhere, anytime soon. And that's determined by global factors. So, will this innovation go elsewhere? I hope so" (Manolin Informant). Manolin is focused and working exclusively in aquaculture but they see that there is some cross-industry potential to other industries where understanding of environmental factors in needed: "*I think you could see it. Um, I think it's possible. I don't think it's going to be anywhere in our five-year roadmap but at some point, yeah, I think it can go elsewhere. I mean a lot of what we're doing is understanding environmental factors, which can be applied for a variety of opportunities"* (Manolin Informant).

5.3. New entrants to the industry

Bergen is very attractive to people looking to establish new companies in the aquaculture sector for many reasons: *"[..] why Bergen then is interesting to externals is because of this proximity to the market. So, if I have an innovation for the salmon industry and if I wanna land somewhere, I should probably go here and start from here. [...] the level of expertise and the proximity of the market, a lot of innovation that is targeting the more direct needs, that stuff that farmers would be quite vocal about such as sea-lice or close-contained systems or offshore system."* (Hatch Informant).

In early 2018, the aquaculture accelerator Hatch chose Bergen as the base for their first accelerator program after considering multiple geographies, but the choice was not clear cut because Bergen as a region has not been visible globally to the degree that even aquaculture professionals understood the importance: "*I think Bergen are not necessarily doing a great job of putting itself on the map globally as a place to go to. So, when we started, we really had not read an idea of the importance of Bergen and that ecosystem*" (Hatch Informant). Hatch chose to establish an accelerator programme in Bergen and has been acting as a significant pull on startup companies to travel to the region. For Manolin Aquaculture, a company that attended the first program in April to June 2018, Hatch acted as a catalyst. When asked if they would have moved to Bergen without Hatch the informant says: *"[...] probably not. We want it to, but I think our own insecurities on how big this industry was would have kept us from doing it. We weren't willing to take that leap of faith. We weren't a leave willing to leave our old jobs to come do this because while we believed in it, I don't think we had enough guts to really do it on our own" (*Manolin Informant).

When Manolin decided on where to locate their company, they had a number of requirements on the regional innovation system and its capabilities: *"I guess the part that we were looking for was this idea that a central place where the government, the scientists, the innovation, the business, the farmers, we're all connected together. Um, places where those interactions happen daily between these parties. That was something that didn't exist anywhere else." (*Manolin Informant). Interestingly, the choice of innovation system also shaped their product development significantly: *"We wouldn't have gone to wherever those, if those four things existed, we would have gone. It's so happened that had happened in salmon and it so happened that it was already a technology advanced niche industry, which helps" (*Manolin Informant).

Bergen has been an industrial hub for aquaculture for many years, and has a unique competitive collaborative environment between the salmon farmers: *"so the Seafood innovation clusters is a very unique initiative and approach of pretty competitive collaboration in that industry specifically for the salmon industry with really like the top, top companies in there. And I think that's, that's absolutely unique, that's also the right way to go"* (Hatch Informant).

Innovation and early stage companies have only recently seen an increase in development speed. NCE Seafood Innovation cluster is an industry interest organization that act as a driver for innovation projects from the industry: "*[...] we sit in a position in most of them called innovation champion [...] (it) is simply a person who connects with all the work package leaders across all sorts of research fields, picks up the findings and make sure they're published accessible to the industry.*" (NCE Seafood Informant). The relative immaturity of the innovation infrastructure compared to other innovation hubs is apparent to the startups: *"I think one of the issues we found was that there wasn't a hub of aquaculture to the scale that we needed for our business. There are small hubs around the world. There are small areas, small pockets, but it, there wasn't a full ecosystem. [...] I don't necessarily believe that Bergen was ready for startups in a sense, but it's a* *more mature ecosystem than anywhere else." (*Manolin Informant). There has also a lack of early stage funding available which has been challenging to get early stage ideas off the ground: "*in terms of support structures, Norway [...] it's just coming up now with like incentives for angels. So really helping finances. Early stage gap and incentives for VC funds to settle here. So that is Norway hasn't done a great job there. And it more look towards these research support and grants rather than private character to do move innovation forward. And I think that's obviously something that I think could be improved and I think would have quite a high return as well."* (Hatch Informant). The missing early stage funding is also the missing part of the regional innovation system that Hatch aims to remedy: "*we invest early where there's a high risk and we also hope to bring on then education expertise, network and all the other things that are required. But on the financial side, we bring capital that can take risks.*" (Hatch Informant).

The Bergen region is very focused on salmon production. NCE Seafood Innovation Cluster, an interest organization owned by the salmon farmers have no projects at this time on other species: "*No, there are no projects of this time encompassing all other aquaculture species. There is simply too little interest. There's too little research to be going on at this time. So there is little innovation going on at this time.*" (NCE Seafood Informant).

Close collaboration between industry and early stage companies in the aquaculture industry is not always straightforward, as the farmers are in a position where they are profitable and are, as mentioned above, very production oriented: "*[...] the farmers right now, in my opinion, are making money and a lot of money and they, they don't need to collaborate with startups"* (Hatch Informant). This is further verified by Manolin, who have had a hard time to get into collaboration with the larger corporates: *"It (The collaboration) has been non-existent"*. (Manolin Informant). They think that the issue working with corporates are a fact that many corporation generally struggle with innovation, and that there are both upsides and downsides to innovation and thus careful consideration is needed, also the small percentage that can be achieved through incremental innovation may be crucial when trying to stay alive, but due to the current financial situation there is not the same incentive to innovate: "*you have to compare it to agriculture companies and you know what they need to do to stay alive. And that's where, you know, changing their business by small percentages that can make huge impacts for their business financially still may not be what they focus on"* (Manolin Informant). Manolin has had greater success working with smaller farmers, who are closer to the ground and can take more informal decisions, and have a quicker innovation loop where answers on what is needed is more readily available: "*Smaller farmers have more issues, but the same person who has the problem is also the same person who can make a purchasing decision. So the fact that you can talk to one person, get your answers, iterate the product and make the sale, accelerates everything you can do instead of having to get so many people in the room at the same time"* (Manolin Informant).

More collaboration and knowledge sharing is also happening between the startups themselves, where during the hatch accelerator program, many of the startups collaborated: "*it felt like there was quite a lot of knowledge and the room specific knowledge and that startups is, they could go to just another desk in the room and ask as quite specific questions and get good answers. And then they felt they are all in the same boat because they, they're trying to sell aquaculture as an investment opportunity to investors,"* (Hatch Informant). Manolin who was a part of the first cohort feels like there was a lot of collaboration between the startups, but also competition, which is helpful for an early stage company to be able to benchmark themselves: *"I think it was hugely beneficial and continues to be. [...] being in Hatch in an accelerator at that early vulnerable stage with others who are in the same situation helps. It gives you a point of measurement. [...] there's obviously the collaboration of sharing ideas and expertise and whatnot. But to be honest, I think it's more of that ability to benchmark yourself"* (Manolin Informant).

In summary, Bergen has been an important aquaculture cluster for many years, but it is only in the last couple of years that innovation in early stage companies has started to flourish. This is partly due to the establishment of the industry interest organization Seafood Innovation Cluster which acts as a collaborative R&D department for industry wide challenges such as the sea lice. Other new initiatives such as the aquaculture accelerator Hatch have established themselves in Bergen to get close proximity to the many salmon corporate headquarters that exists as well as the supplemental specialized RIS that surrounds the industry and thus be able to attract cutting edge aquaculture startups from all around the world. The cooperation between the early stage startups and the salmon corporates is not well established, and this may impact the knowledge sharing and thus weaken the innovation system. While Bergen is an aquaculture hub it does lack some infrastructure that is needed for startups to success, such as risk tolerant venture capital investors.

5.4. New products in the industry

Open pen farming is seen as very probable to continue to be the dominating production technology in the future: "*I mean it's a very good system, right? Like why would we need to change something that's working pretty well? If you look at the FCRs, if you look at the mortality rates, if you compare that to other industries, if you look at the environmental footprint of those, I don't think that there is something, like innovation needs to solve a problem right.*" (Hatch Informant). The Salmon farmers are also confident that salmon farming will continue as it does today, even though many of them have tried to farm other species: "*[...] the value creation you can get from salmon you don't really see in other species. As long as there is a growth potential that's where the investments will go first.*" (Grieg Seafood Informant). The salmon is a species where the biology is "solved" and thus the farming is more predictable than for other species: "*[...] halibut, cod, [...] every species has its challenge. Salmon is something they have figured out*" (Grieg Seafood Informant). Not only is the farming predictable, the regulations for acquiring new salmon farming licenses in areas where previous farming exists is less complicated than new areas: "*We see that local authorities and regulation is very important for our operations. Every time you enter a new production area, there are new regulatory things to adhere to. That is a challenge.*" (Grieg Seafood Informant).

5.5. The future of salmon farming industry path

While open pen farming of salmon seems like the most lucrative way of farming, the limited licenses and new technological development also have spawned new production systems that may change salmon farming in the future. There are potentially three major disrupting production technologies: "[...] *One is offshore technology or closed technology in sea that makes it much easier to start and operate sustainably, but it's going to take some time to establish. Then its land-based, where new entrants are popping up every day. But most of them are small and none of them have a substantial production within the next 10 years [...] then it's of course clean meat where the question of time until you get the large volumes, where the large risk is in the 10+ years from now*" (Grieg Seafood Informant). There are however not only positives with new production systems, as many aspects have to be taken into account in the new systems: *"I don't have numbers on it, but for example, you know, lab grown meat as well as, you know, land-based salmon, you* *gotta be careful. These other production systems, while the positives look very good, there is obvious negatives to it as well, whether it's energy usage output, um, animal welfare, sourcing materials, there's it, these are complex systems" (Manolin).* But at the end of the day it will come down to costs: "*[...] as with all production technologies, cost is what it comes down to after all. It is vital to be cost competitive*" (Grieg Seafood Informant).

On the technology side, salmon farming is poised to become more technically advanced farming in the future: "*[...] I think you hear that from across the industry. [...] for sure tech is going to get more involved" (Manolin).* Many of the operational processes will change due to enabling technology: "*I think there will be more automatic processes. Personally, I don't think feeding will be manual, which will lead to a lot less people. These people may have to readjust to do something else than they do today.*" (Grieg Seafood). This new digital future of salmon farming may also change the requirement for the employees: "*The future employee is much more digital, and maybe not a farmer anymore, but you are more specialized in your tasks. You are a technical person or a health biologist in greater degree*" (Grieg Seafood).

On future consumption of salmon, the Manolin informant states: "*I think consumers will continue to eat salmon. I don't see it going anywhere.".* And while the consumption might continue there could however be a divergence of products in the future to serve a market that is more differentiated: "*In 10 to 15 years I believe that there will be different niches, and that the Norwegian salmon could be a brand, but then more linked to ocean produced salmon"* (Grieg Seafood Informant). The markets may also change due to sustainability trends: "*as the focus the climate has gotten now, I don't think we will airfreight salmon in 15 years [...] airfreight markets will not be as reasonable, and there may be more of a regional focus*" (Grieg Seafood Informant).

To sum it up, there are immature competing production technologies for salmon farming, and salmon farming itself is becoming increasingly more technologically advanced. As consumers are likely to continue to eat salmon and the demand is good, there is little worry that a major disruption will happen, but that there may be a slight differentiation in the market in the future. Salmon farming will likely continue in the same path since the invention of open pen farming. On the question if we will continue to produce fish in the same way but more efficiently in the future, the NCE Seafood Informant states: "*I Literally think that's going to be the picture for the next 20 years. Further than that I have no idea".*

5.6. Summary of salmon aquaculture analysis

In this chapter I have analyzed RQ1: *What characterizes the salmon industry path in the Bergen region?* I made two assumptions in chapter 1.1.1 in connection to this research question to better structure the analysis.

The first assumption made for this chapter was: *Salmon farming is mainly experiencing substantial incremental innovations.*

In part four, *Outlook and emerging Issues,* of FAO's The State of World Fisheries and Aquaculture from 2018, aquaculture is said to experiencing disruptive technological innovation. FAO defines disruption as "drastic alteration or destruction of existing things or elements of society" and further gives examples such as LED, computers and smartphones as examples of disruptive innovation. In aquaculture it is clear from both the literature and interviews that new technologies are being implemented and utilized in aquaculture, such as mobile internet, digitalization, blockchain, robotics and advanced sensors. FAO argues that these new technologies will disrupt aquaculture and change the way the sector does business (FAO, 2018).

I would like to argue that while these innovations will disrupt, create new aquaculture processes and change the way businesses operate, the fundamentals are still the same as aquaculture was 5000 years ago. Fish are contained in farms and are fed to reach a weight where they are harvested for their flesh to be used as food, and as chapter 5.5 states, salmon farming will likely continue to be farmed in open-net pens in the foreseeable future.

While the Norwegian salmon farming is experiencing incremental innovation, it does not have to mean that its slow. As mentioned by Manolin in section 5.2, the innovation pace might even be faster than agriculture due to pressure from increasing sustainability through stricter regulation. The innovation is lead from a top-down approach where the government has enforced a system that benchmarks the industry against the number of salmon lice at the farming sites which has led to an industry where everything is revolved around salmon lice and most of the innovation is focused around lowering the lice numbers. There are also forced innovation through governmental incentives such as the development licenses, and thus the salmon industry has no choice but to find innovative solutions to be able to increase their salmon biomass, which is the common goal of the company's owners.

The second and final assumption made was that: *The salmon farming industry path is in a stable state*.

Salmon farming is the dominant industrial path for aquaculture in Norway which is evidenced by the biomass production in Norway consisting of over 99% salmon in 2017 (Norwegian Directorate of Fisheries, 2018). The farmers have good margins and these margins are assumed to continue due to the prediction of stable high salmon prices while costs will not increase dramatically. The salmon farming path is in what Martin (2010) describes as a positive lock-in, i.e. high degree of standardization of the production and distribution system, low production costs, and increased return effects. This also means that the path is in a stable state with a reinforcement of selected production and distribution forms (i.e. open net-pens, standardized products) and well-established industry networks and knowledge systems (see chapter 2.3).

One reason for the path stabilization is lock-in mechanisms from the salmon farmer owners who push for increased optimization of salmon production to exploit the considerable profits that salmon farming is providing. There are further lock-in mechanisms through the specialization of the RIS surrounding the industry, where Bergen has become a world leading aquaculture hub that is knowledge-, technology-, regulatory- and process-specialized in salmon farming. As the paper by Aarset & Jakobsen (2015) concludes, there is limited co-evolution potential with other industry paths such as cod farming since of this specialization. Other arguments for the stable state of the salmon farming industry path is that there have been almost no change production volumes over the last five years, as presented in chapter 4.1.3, and the barriers to entry are significant due to cost of entry as shown in chapter 5.1.3, that the prices for a license have more than doubled since 2014.

There is little interest to diverge from salmon farming as it exists today due to the positive path lock-in experienced by the industry, and since the future looks promising there is little reason to do any major disruptive changes of the industry, but instead focus on incremental innovations through new technology to optimize farming such as machine learning, automation, digitalization, robotization and develop new solutions to handle the salmon lice.

To sum up this chapter and answer the RQ1: "*What characterizes the salmon industry path in the Bergen region?*" we can conclude that Bergen in Norway has a specialized seafood sector that has been developed due to the success of the salmon farming industry path. Bergen contains a regional innovation system (RIS) with a section that is tailored to aquaculture with institutions such as the Institute of Marine Research, University of Bergen offering world leading aquaculture research and education while NCE Innovation cluster acts as an innovation arm for the salmon corporates and Hatch as a platform for early stage innovation. This regional innovation system also includes several related industries that can provide the seafood sector with knowledge and technologies important for the development of a sustainable industry path. One example is the technology firms within the oil and gas sector that has contributed towards developing new alternative production technologies, that now are being tested by some of the salmon producers (i.e. land-based aquaculture or semi-closed systems).

Since the resources needed to farm animals traditionally have been available in specific regions, aquaculture has been bound to these regions. Since salmon aquaculture is conducted along the coast, much of the industry has been bound to operate close to the coast. The limited areas that are suitable for aquaculture has created initiatives to expand the available area by means of developing new technology such as land-based aquaculture, semi-closed system and offshore aquaculture. These new production methods are early in their development and not utilized to their full potential and could provide a possibility for aquaculture to become less geography dependent. In the interviews, however, the informants expect open pen farming to continue to be the dominating form of farming in the foreseeable future which in that case would continue the existing attachment to geography. This means that geographical proximity between suitable localities close to the coast and the production of salmon will still be an important dimension for the salmon farming industry.

This salmon industry path in the Bergen region is in a stable state with positive lock-in mechanisms that will make the industry prioritizing further optimizing of the salmon production though incremental innovation but reluctant to disruptive innovation. Regarding the classification of different development path for an industry presented by Isaksen et al. 2014 (see chapter 2.3.3), one can argue that the salmon industry in the Bergen region is mainly characterized by path extension, but with some elements of path renewal.

6. Cell-based seafood analysis

In this chapter, I have analyzed the second research question RQ2: "*What is the status of the cell-based seafood industry?*". Cell-based seafood is an emerging global industry with incumbents on several different continents around the world. Interestingly several of these early entrants in this industry have clustered together in San Francisco, USA. Thus, I have conducted interviews with key stakeholders in the cell-based industry in this area to unpack the characteristics of the industry. This chapter is based on interviews with five representants from different parts of the San Francisco clean meat industry: 1) *The Good Food Institute (GFI)* to represent the views of a clean meat interest organization, 2) *IndieBio* to represent the views of a biotech startup business accelerator and 3) *Finless Foods* to represent the views of a seafood focused startup in the clean meat industry, 4) *New Age Meats* to represent the views of a meat focused startup in the clean meat industry and 5) *Mission Barns* to represent the views of a species-agnostic startup in the clean meat industry.

The first chapter 6.1 covers different aspects of San Francisco and what it offers to startups, 6.2 covers clean meat and the preferences for locating the industry in certain regions, 6.3 is a chapter on the status of the industry, 6.4 digs into the R&D and technical aspects, 6.5 is a chapter that explores the possibilities for cross industry innovation with other industries, 6.6 covers the status of the industry in a theoretical aspect and finally 6.7 is a summary of the analysis on cell-based seafood.

6.1. The San Francisco clean meat cluster

The clean meat industry has some centers where the development has historically occurred. Today much of the development happens in the somewhat more established companies that are spread around the world but early stage entrants to the industry cluster together in San Francisco. San Francisco has a history of startup due to its proximity to Silicon Valley, and in many regards both systems can be counted as one since there is little divergence in terms of actors, regulations, proximity and knowledge pool. San Francisco is known to provide a pool of willing venture capital (VC), specialized talent, infrastructure and knowledge sharing, all which is critical for early stage startups. The region is also more willing to invest in so called "moonshots", which are companies that are very high risk but very high reward: "[...] *they have enough money that their mission is on that hundred x growth [...] And that is the mission of all of the VC's there. And when you're a via evaluating the world from that perspective, it means you have to take risky opportunities."* (Manolin Informant). Due to the potential to disrupt the foods system, clean meat is a potential moonshot-industry, and thus fits into the strategy of the venture capitalists: *"I would argue that* *biotech and clean neat sits in that space. Yet they're looking to create new markets, new markets that have potential to be huge versus solutions that fix existing markets.*" (Manolin Informant).

Infrastructure and knowledge on how to start business is offered as a service to companies through privately funded business accelerators. IndieBio is one of those accelerators that operate in San Francisco and has established itself as a very attractive option for biotechnology companies. Many well-known companies in the clean meat industry have gone through the IndieBio program and only moved to San Francisco for that reason: "[...] *people move here to companies move here to get funding to get, I mean get for example in IndieBio, I mean they think you're a big pull on companies to come here"* (IndieBio Informant). San Francisco has a rich history of startup and entrepreneurship activity dating back to the telecom industry in the 50s. The well-known Silicon Valley technology cluster has had a big pull on tech startups and the whole tech industry and have created specialized large venture funds to fund this kind of risky early stage activity. This movement has spilled over into biotechnology and works on the same premises. Clean meat, which is far from market, risky and challenging but potentially astronomically profitable once the barriers are breached is an investment opportunity that the venture funds are specialized to handle.

San Francisco has been a cradle for the clean meat industry thanks to its entrepreneurial spirit: *"It started very US based, US and Israel and I think that's not a coincidence. It's because those in those places how such robust innovation, um, you know, kind of entrepreneurial hot beds and so no idea is too out there to get traction in those areas."* (GFI Informant). While there is a lot of activity in San Francisco, the startups themselves do not see the area as crucial to their progress but it has agglomeration advantages of having many startups there already: "*I think we're not tied to necessarily the bay area. We're tied to making this dream happen. And so, uh, yeah, we'll do whatever it takes. I think obviously, you know, the bay area, it has its advantages, a lot of synergies as you said here. It's quite a nice place, but this isn't so much of a geographically based technology.*" (Mission Barns).

6.2. The geography of the clean meat industry

The clean meat industry is not necessarily tied to a specific region, and there is starting to become interest from all around the world for establishing cell-based initiatives, and often from a top-down governmental push: "*So we've seen governments in Japan, for example, their sovereign fund has* *invested in this space. Singapore is about to announce quite a bit of money going into this space. I even was aware of some more on the public research side of things in India, some announcements that should be in the next month or two*" (GFI Informant). The interests from governments to establish this industry in their specific region is not only to create jobs though, but also to secure their future needs: *""[...] a lot of interest coming from Asia now, and a lot of that actually coming from the governments who are looking at this as a food security issue."* (GFI Informant). The motivation to move into the space from a governmental side could also be driven by a technological advantage: "*governments who are looking at this as, as you know, some things that one, they can have some technological advantage. So, you know, places like Singapore and Japan have the time, expertise and they think they can have an upper hand here from a technology perspective.*" (GFI Informant).

Startups might even welcome more development in other regions: "*I think it'd be wonderful if there were growing ecosystems. [...] We're very excited to, to follow up lots of what's happening about China in Israel.*" (Mission Barns Informant). The "footloose" nature of the industry means that the startups are aware the industry could unexpectedly emerge somewhere else: *"It absolutely could happen elsewhere because, [...] look at China, [...] Singapore's at a ton of money that the government is a far more invested in the good of the people.*" (New Age Meats Informant). There has been some fluidity in the early stages of the space, as new niches were still discovered in clean meat and adjacent spaces: "*I've seen the clean-meat space grow from nothing to where it is today. [...] it's been a really exciting, and Modern Meadow very early on when they were still making meat. So yeah it's been kind of a fun few years for food tech for sure.*" (Mission Barns Informant). Not all startups succeed, but even this turnover of companies in biotechnology is important: "*there's so many biotech companies here that are like forming and failing all the time that it's like the jungle floor. There's just like equipment everywhere for sale.*" (Finless Foods Informant). While the San Francisco environment has been beneficial for the early stage companies, it is not necessarily advantageous for the more mature startups who are leaving the R&D stage: *"There's no reason to stay. I mean, this, all this stuff that like used equipment and [...] the investment environment, those are the things that you really need when you're small, but not necessarily when you're big"* (Finless Foods).

6.3. The status of the clean meat industry in San Francisco

One of the first startup companies to try to commercialize cell-based meat was Memphis Meats which attended IndieBio, a business accelerator invests in two cohorts of companies a year focused on biotechnology in San Francisco: *"We're just coming up on four years [...] Meat itself started in class number two. Our first food company Clara foods, number one, making egg white, number two was Memphis meats"* (IndieBio Informant). The role of the Memphis Meats can be seen in many ways as a first-mover in the cell-based space, and acted as a catalyst for other startups to work on cell-based meat: *"Memphis raised this whole kind of movement to took the momentum or somewhat lack of momentum of like the PETA's mercy for animals, like the animal rights nonprofits who said don't eat meat but didn't kind of connect like, so I don't eat meat"*(IndieBio Informant).

While there was a link to the animal rights movement, as a strong support group for the idea of clean meat, funding was harder to obtain in the early days of the industry. This is confirmed by IndieBio, who have been funding early stage companies since the start: *"three and a half years ago it was definitely a very different landscape [...] people were very excited, and Wall Street Journal came and cover them. They had tons of press, but um, money, it wasn't flowing the way it is."* (IndieBio Informant). Funding in the early days of the clean meat industry came from the animal rights and vegan movement: "*I think that was the first group of like true believers, so to speak, in backers of these companies. But in terms of investors, there was the Glass Walls Syndicate, this is a term for a group of investors around specifically begin and replacing animals in the supply chain companies*" (IndieBio Informant).

Finless Foods was the first cell-based seafood company: *"We were the first company to ever create, cell-based seafood that was eaten and also the first cell-based anything company to feed what it made to a reporter"* (Finless Foods Informant). The inspiration to pursue clean meat came from discovering how biotechnology could make synthetic equivalents of biological compounds extracted from animals in inhumane ways: "*in 2014 i read this protocol called the blood harvest. And it was in the Atlantic [...] it got me just down this line of thinking. [..] what if you just grew meat outside of an animal? [...] at the time in 2014, it was done, which was cool that people were already working on it. Modern Meadow already existed. Mark Post had already made his burger [...] I was like, okay, so I'm not totally crazy.*" (Finless Foods Informant). The perception that the idea of growing meat outside of an animal could be perceived as "crazy" speaks to the novelty and disruptiveness of the industry. The early stage of the industry is reflected by the fact that many of the companies very recently have gotten their first major investment rounds secured: "*We had this event with that event we raised $3.6 million to build this facility, hired up a bunch of people and, yeah, that's more or less where we're at*" (Finless Foods Informant). There is an acceleration in the development of the industry: "*I think it's a nonlinear kind of acceleration of the space because once these companies see each other getting involved with, then it really lights that sort of competitive fire. Um, and they, they all, you know, are incentivized to move much more quickly than they would if they didn't see this whole landscape evolving*" (GFI Informant). One explanation for the acceleration of the space is the acceleration of biotechnology in general: "*biotech in general now it's gained a lot of steam and most funds will look at biotech even once in a classic pure like tech and IT have started to hire a partners in bio*" (IndieBio Informant).

As incumbents enter a new industry, they naturally seek to find niches and opportunities with least competition: "*I think there's been a good segmentation and part of the niches in the industry. I think at first, you know, when Finless Foods started, it was kind of the thesis was that Memphis Meats wasn't really doing that much seafood.*" (Mission Barns Informant). Mission Barns, who is focused on fat cells choose their niche at least partly based on the fact that there were few other companies specializing in fat before them: "*we were trying to occupy a niche that at least people weren't very much focused on previously. More and more as you start seeing new companies, then there's less niches to carve that are attractive.*" (Mission Barns Informant).

6.4. Technological developments and research

The technology used in the industry is based on stem cell and tissue engineering and is thus dependent on progress made in those closely related fields: "*[...] technology seems to be converging. Like this field is fundamentally based on stem cell technology in a sense. And that had to advance I think whereas two decades prior was probably far too young when the hype cycle in the US.*" (IndieBio Informant). Much of the technology is also applicable to various types of tissue and species, which means that land-based meat and seafood shares much of the overarching technology. There are however a varying degree of difficulty working on different tissues and cells: "[...] *making fat is very similar to making other types of tissue. I mean has a lot of advantages. We'd proceed from a technical standpoint; we've been able to do some things in our view faster* *than we would've been able to had we've been focusing on different tissue types.*" (Mission Barns Informant). When drilling down further into the specifics, there are biological variations between the cells that creates some barriers in knowledge transfer: "*[...] fish, it's very broad. [...] some of our cells actually don't even really have the same morphology just don't react to the same types of conditions. There's overlap but not always.*" (Finless Foods Informant).

There is a difficulty in knowing exactly how much technology can transfer within the industry between different species: "*right now everyone's trying to solve kind of similar problems but doing it in their own silos as opposed to being solved for everyone though. If (Finless Foods) solve it for Bluefin Tuna, how much, if any of that translates over to New Age (Meats) is a big question for me."* (IndieBio Informant). If this will lead to divergence between species into separate industry path is something that is not implausible, but it is too early to extrapolate when the overarching clean meat industry is in such a nascent state. The state of the industry also has an effect on how much information the companies are willing to share among themselves, because the patents and other IP may not be granted yet: "*[...] right now it's kind of a, an especially sensitive time for the industry because a lot of the companies are so new that if they even had a chance to file their, their patents, they haven't gotten those patents fully reviewed and granted, yes. And so they're just kind of sitting on [...] a lot of information or technologies that they can't quite talk about yet*" (GFI Informant).

The clean meat is very dependent on highly specialized and educated human capital: *"[...] (We) hired a geneticist[...] I'm moving the bioinformatics [...] in house, moving our food science in house."* (Finless Foods Informant). Much of the knowledge in the industry is analytical due to its roots in academia and highly technical nature with the needed specific knowledge: *"[...] almost our entire team except for me are scientists and engineers.*" (Mission Barns Informant), and this has led to many of the hires in the industry being done straight from the universities in the region: "*[...] Berkeley, so we find a lot of really great people over there [...] there's UCSF. We've had from those multiple times"* (Finless Foods Informant). As the industry has somewhat become more established, more people with higher competence and caliber has been drawn into the field: *"I would say in the cell-based meat side of things, it's a very different world than it was three years ago. Um, not only just in the number of startup companies, but you know, more of interest to me and sort of the caliber of people getting involved"* (GFI Informant). Higher caliber competence is needed, as the field is challenging. As the Mission Barns informant puts it: *"Clean meat it's a hard* *problem and we're all trying to tackle and do something very new and if it was easy, someone would have already done it.”*. There are many different processes that needs to be integrated with the core cellular biology that the industry is using to develop edible tissue, which has led to the need to outsource some parts of the production: *“cellular biology so far we've done it in house. We've outsourced a few things in terms of our science, but the actual like cell breeding, essentially, that's all us. Our proteins are made by microbial fermentation. We've outsourced that fermentation and also the creation of the microbial strains that will do that. [...] we've outsourced a bit of our bioinformatics”* (Finless Foods Informant).

There is ongoing knowledge transfer between the established industry and clean meat: *“the Tyson people come through and the Monsanto people come through the Bayer people come through”* (Finless Foods Informant). The type of knowledge that these established companies have and also venture capital people are willing to help: *“[...] obvious ventures come through”*. As the clean meat industry is still immature, there is a need to work with large companies to solve some of the technical challenges with scaling up production: “[...] *it will probably be a big joint venture partnership with some big company that has scale-up facility to distribution*” (GFI Informant). Partnering with clean meat is becoming increasingly interesting for the established industries: *“it's a very different world than it was three years ago [...] by that I mean in part interest from parallel existing established industries”* (GFI Informant).

Research and development for early stage companies are often guided by experienced mentors and parties that at times can dictate the terms. Early stage venture capital investors are understanding that the entrepreneur will be leading the project, while larger companies that enter a joint venture (JV) with an entrepreneur might not view things the same way, and could thus be a barrier for collaboration: “*with our investors if I don't like what they say. [..] (I can say) we're not going to do that. [...] if someone's doing a JV with us, I don't quite have that luxury.*” (Finless Foods Informant).

There is ongoing public research in the clean meat industry sector, mostly funded through non-profit organizations such as the Good Food Institute (GFI) and New Harvest: “*You need funding from somewhere, cause often times government isn’t the source of funding of this magnitude.*” (New Age Meats Informant). Research in this field is capital intensive which may have contributed to the relatively sparse literature available: “*There just hasn't been a ton of public research [...] I think New Harvest in total over its lifetime has deployed $1 million [...] GFI just* *deployed $3 million all at once, which is great, so hopefully that changes*" (Finless Foods Informant). So there has not been much public research conducted so far, and most is academic researchers: "*The vast majority of the projects that we funded were academic researchers because we had a requirement for eligibility that you have to be willing to publish the results of what you found with that money*." (GFI informant). This requirement has led to startup companies not been able to apply and utilize the money for their own R&D as: "*they wanted to have as the sort of exclusive, you know, intellectual property.*" (GFI informant).

Finless Foods have investigated the possibility to work together with "fish companies", which covers the companies that produce fish through aquaculture and sell their products to other businesses (B2B). As the production methods for cell-based fish and traditional fish are very different, they see that production wise, there is not much to gain: "*They have some knowledge, which is great, but [...] they don't know how to do a bioreactor [...] and they don't know how to [...] solve production. [...]the technical aspects of cell biology [...] large-scale industrial production. They don't know how to do that*" (Finless Foods Informant). To solve the production scaling, Finless Foods believe that there is more to get to integrate with large pharma producers since they are closer technology-wise. While the actual production might not be where most benefit is, they see other parts of the value chain as more interesting when considering working with the established aquaculture industry: "*It would help us with like packaging, advertising, marketing sales channels*". The salmon farmers have large sources of capital as well which is beneficial for early stage R&D heavy companies such as Finless Foods, but the capital will come at a later stage when most of the initial barriers are passed: *"it would basically just be like a source of capital that would than help us on the tail end."*

6.5. Cross industry innovation potential with established industries

As the industry matures, there are other considerations to take into account, and it is where to get the knowledge to scale the industry, and how to think about the industry at a more mature stage: *"I think we really do need to be thinking of this more akin to an agricultural system [...] we have to learn how to make that work in a large-scale production environments make it economically viable"* (Good Food Institute). There are certain industries that are interesting for the clean meat industry to adopt innovation from, in so called cross industry innovation, presented in chapter 2, where "already existing solutions from other industries are creatively imitated and retranslated to meet the need of the industry's current market or products." (Enkel & Gassman, 2010). Most of the startups are already exploring possibilities in other industries: *"we have a lot of relationships, [...] (we) certainly talk a lot to meat companies. [...] we talk to other companies, whether it's biotech companies that are suppliers to us or vendors or partners to co-develop new technology in the future."* (Mission Barns Informant).

Large animal producers with inhouse competence and expertise in multiple parts of the value chain, not only farming animals, have a lot of cross industry innovation potential with clean meat: "*who better to help you get that need just right than a team of meat scientists.*" (GFI Informant). There is also the downstream processing when it comes to actual products: "*packaging and any follow-on processing or you know, product development, etc.*" (GFI Informant). The producers may also have a lot of basic science in house: "*those companies certainly have a lot of that kind of animal science, animal cell biology, kind of expertise*" (GFI Informant). Some of that science could potentially be transferred to cell-based meat as well: "*animal science and animal genetics programs. [...] I think some of those traits will translate directly to a cell-based meat production environment*" (GFI Informant).

There is increasing vertical integration in certain sectors of the traditional animal farming industry such as chicken and pork where a single supplier will own the whole supply chain because they have the ability to consolidate many of smaller companies by acquisitions. The Informant from New Age Meats explains the situation for beef: *"a large upstream pipeline where the cows come from, they come from small ranches. [...] then they're fed into the larger ecosystem. In our new model, [...] the larger companies, these could shift, right? These guys out here and won't be able to."*. A situation like this is concerning for the smaller suppliers who occupy the protein production niche is the supply chain, which is the same niche as the clean meat industry will occupy in the future. Thus, in the beef industry, clean meat can be seen as a real threat, for the smaller farmers: *"which is why you see all of the blowback. Almost all of it comes from the cattlemen. Cow and beef association. You hardly hear anybody from a chicken or pork or anything like that."* (New Age Meat Informant).

The relation with the life science industry is different, since clean meat will not directly compete with their product lineup but will instead act as a new industry that the companies can supply products, services and knowledge to. The interest has increased significantly in the last couple of years: *“two years ago, I was calling up life science companies [...] telling them the industry on behalf of which I was asking these questions and you'd get sort of the eye roll, like, "wow, that sounds very sci-fi"”* (GFI Informant). Whereas now the companies are much more interested and some very large life science companies have already started investing and feeling an urgency to move fast: *“[...] companies like Merck actually making investments and starting up innovation arms specifically around enabling technologies for cell-based meat, um, you know, companies coming to us and saying, wow, you think we are actually now a few months behind this trend.”* (GFI Informant).

The knowledge transfer potential working with the life science industry is substantial: *“These are the folks who know how to do large-scale animal cell culture and have all of the tools and technologies at their fingertips to figure out how we go to an actual industrial scale production environment”* (GFI Informant). Among the most interesting specific industries for the clean meat startups are: “*Tissue engineering and bio manufacturing. The two big ones. Traditional pharmaceutical companies have media development and other techniques*” (Mission Barns). The industry will certainly become important when scaling up operation and producing at large-scale becomes important: “*The only system on earth, the kind of replicates what a clean meat factory would it look like? Is the Samsung thing in Korea, they have 320,000 liter capacity production of animal cells in order to produce biologics, pharmaceuticals*.” (Finless Foods Informant).

One industry that will likely play a large role in the future of clean meat is the ingredients and chemical industry that will provide the raw materials and thus could fill the role as a feed supplier: *“the big chemical industries of the world that are supplying all the salts and sugars and amino acids, they go into the cell culture media”* (GFI Informant). The large ingredient and chemical companies have an opportunity to work with the industry to develop improvements and optimization of the materials, which is not something that can be done in all industries: *“That doesn't necessarily work, say for an application like Biopharma. Um, so I think they have an opportunity to get much more involved.”* (GFI Informant).

While the opportunity is seemingly promising, the companies are still behind the life science companies: *“[...] they don't seem quite as far ahead as folks like Merck”* (GFI Informant). This is most likely due to the fact that the startup companies are focusing on the immediate needs and milestones, and feed will be more important as the scale of the industry grows. There is also an opportunity for the companies that are supplying ingredients to the animal feed industry to get involved *"[...] what would it take for them to process those raw materials in a way that's suitable for, you know, going in as a feedstock to cell culture"*(GFI Informant). In this category we also see food science as an important industry as the engineering of flavor and texture is specialized advanced knowledge: "*Food Science is really important deal for us [...] flavor chemistry, texture chemistry.*" (Finless Foods Informant).

There is not only collaboration when a new industry emerges. Competition will cause friction, and this can be seen in the US, where regulations lobbied by the cattle producers are creating barriers: *"they'll fight against you and they'll use the dirty tricks that they have in their disposal. The state laws that you see now are dirty tricks."* (New Age Meats Informant).

6.6. The clean meat industry as an emerging industry path

Developing clean meat products is a significant challenge for the involved companies. Much of the struggle stems from both the novelty of the field but also the novelty of the technology: *"[...] clean meat it's a hard problem and we're all trying to tackle and do something very new and if it was easy, someone would have already done it."* (Mission Barns Informant).

The cell-based industry is in an early stage in terms of technology and research, and it still only represents a potential for path creation. Companies often have to resort to basic research since there is little done, due to the novelty of the field: "[...] *we've had to do a lot of basic research. There's not a lot going on in animal cell biology. You can read every paper in a week. If you want there is cell bio, it's very sparse. Um, we've had to do a lot of, you know, genome sequencing and characterizations cell morphology characterization, like the basics.*" (Finless Foods Informant). The companies in the field are working on developing products for early stage research: "*We met with quite a few companies [...] A lot of them were working on media. There were some working on maybe cell-lines. There wasn't too many working on bioreactors and scaffolding down the line, which makes sense since its further down the development cycle. Most companies care about that later. Most of the companies coming into the space cared about developing products for early stage research, where they were.*" (New Age Meats Informant). The field is highly technological, even to the degree that some of the companies identify as "tech companies": "*We're really a tech* *company where we're building a tech platform. On one of the kind of areas of focusing first on, on one of the main areas of clean meat*" (Mission Barns Informant).

When the startups are asked about when they will reach the market and launch their products, the answer is often "[...] in *a couple of years*" (New Age Meats Informant). While the question is quite vague of what going to market means, if it means putting one product in one restaurant or losing money on each sale, there is also the importance of having safe product when entering the market, as the New Age Meats Informants puts it on companies that may rush a product to market: *"If they are thinking about doing that and they should slow down and think about the overall impact on the market."*

There are unsolved technological challenges, no products on markets and few companies in the industry but at the same time there is increasing media coverage and massive monetary and environmental opportunities to solve these problems, and these factors have spawned many new entrants to the field: *"[...] there's so many new startups kind of joining the space every month or every week, it seems like"* (GFI Informant). There is a challenge for the Good Food Institute to allocate their resources sensibly when there are many new entrants which are not bringing as much to the table as the more established ones: *"[...] certainly other industries that have been in a similar situation has figured out the right parameters to make this work, but it's certainly not an easy process."* (GFI Informant).

6.7. Summary of cell-based seafood analysis

This chapter has been an analysis of the RQ2: *What is the status of cell-based meat and seafood industry?*

San Francisco as a region is attuned to moonshots, meaning that the abundant venture capitalist in the region are willing to invest in high risk-high reward ventures, and clean meat is such a moonshot opportunity. The funding as well as access to infrastructure, knowledge and talent means that early stage clean meat companies have agglomerated in San Francisco. Many startup companies in the clean meat industry is located in San Francisco, and that includes Finless Foods, one of the most advanced cell-based seafood startups. Much of the early stage development is centered around laboratory work, acquiring funding and finding highly specialized talent. Finless Foods and many other companies in the sector moved to San Francisco to attend the biotech accelerator IndieBio which specializes in early stage biotechnology companies. There are other regions that are interested in the clean meat industry, such as China, India, Japan, Israel and Singapore but these countries have a more governmental agenda on food security as motive. Israel has come a long way, as that is potentially as it is also an entrepreneurial hotbed, but as the situation looks like now, the center of the industry is still in the US, specifically San Francisco.

In the introduction in section 1.1.2, a couple of assumptions were made, and the first one was: *cell-based seafood has considerable cross industry innovation potential with cognitive proximate established industries.*

As the clean meat industry is in an early state, there is ample opportunity to learn from other industries on not only how to develop the products but also how to model the value chain of the industry when it reaches a more mature stage. There is significant potential for knowledge transfer with three main industries if the clean meat industry is going to scale up into significant production volumes: 1) Traditional meat producers for expertise in genetics, meat quality and downstream processes, 2) Life sciences for production and processing knowledge, and 3) Ingredients and chemical industry for the knowledge of feed nutrients, flavor and texture that is needed for large-scale production.

The second assumption made was that *the cell-based seafood industry path is nascent and in an early pre-formation phase*

There are still hurdles to overcome until the clean meat, and the included cell-based seafood industry, have a viable production pipeline and value chain for industry scale production. The industry still only represents a potential for path creation (see chapter 2.3.3). As the cell-based seafood industry has yet to develop any products that are available on the market it is difficult to establish the industry as an established path. There are not yet any increasing returns, build-up of skilled labor or knowledge pools nor the geographical establishment one would expect from a mature industry path. From Martin (2010), the preformation phase of an industry is based on preexisting local conditions such as technology, competence and knowledge.

To sum up the analysis we can draw the conclusion that cell-based seafood is a global emerging industry, that is not necessarily attached to a certain region, but where most of the activity at the moment is clustered in San Francisco due to the favorable startup climate. There are many technical hurdles the industry has to solve and will be looking at industries that are cognitively proximate to draw on cross-industry innovation to solve these hurdles.

7. Industry Comparison

In this chapter I will answer the third research question RQ3: "*What are the differences and similarities between salmon farming and cell-based seafood production?*" By comparing salmon farming with clean meat to understand the similarities and differences and thus also where there are areas of possible collaboration and/or cross industry innovation. The chapter will serve as an analysis of several key industry traits in regard to innovation theory, especially EEG, and features a table of the most important traits and factors in the two industries. In the following section I will discuss path development phase, geographical attachment, knowledge base and innovation mode. Table 2 gives an overview of these different dimensions.

Industry	**Path Development Phase**	**Geography**	**Knowledge Base**	**Innovation Mode**	**Key Actors**
Salmon Farming	Stable State	Attached, regional	Synthetic	DUI	Established Salmon farmers, Feed Producers, Interest organizations, Technological Suppliers, Banks, Governments
Cell-based seafood	Pre-Formation	Footloose, multi-scalar	Analytical	SUI	Startups, Venture Capitalists, Interest Organizations, Biotech accelerators, Animal Producers, Food Producers, Governments

Table 2. *"Industry Comparison Table"*

7.1. Path development phase

Chapter 2.3.2. Introduces *Figure 1: "Toward an alternative path dependence model of local industrial evolution"* from Martin (2010) which is an overview of path development trajectories. I would like to argue that cell-based seafood can be viewed as being in a pre-formatory state. An industry will start in a preformation phase where local economic and technological structures, competences and knowledge is utilized to form a path. It can be argued that clean meat falls in this category as the interviews and the literature show that the industry is nascent enough that no real supply chain exists, there are many unknown processes, rapid opportunistic emergence all over the world and there are still large gaps in knowledge on how to actually bring this product to market.

Compared to cell-based seafood, salmon farming in the Bergen region, and in Norway in general, is a mature industry with a specialized value chain, competence and regulatory framework. From Isaksen 2018, characterize the Norwegian seafood industry as an industry following a stable trajectory but at the same time there is some upgrading ongoing due to the push from the government to develop new technological solutions to minimize the environmental impacts of the industry.

Using triggering points as a measure of development phase, salmon farming reached a trigger point in the 60s when there was enabling technology that made farming in the sea possible, and thus made the salmon farming path competitive on a global scale which also increased specialization of the region. Clean meat has not reached a milestone like this yet, as the industry is not yet established. It is very reasonable to assume, based on multiple interviews and the literature, that this event will be one of the technologies that make large-scale production possible. The key bottleneck in the industry when it comes to competitiveness to alternative product such as traditional meat and fish is the cost of production. Cost of production is as described in chapter 4.1. is mainly driven by the cost of growth medium, thus one can argue that the triggering point for the clean meat industry will be the development of cheap enough media that will bring the costs of production down and unleash a sustainable industry path with self-reinforcing mechanisms, as is discussed in the theory chapter 2.3.

7.2. Geographical attachment & spatial scale

The attachment of the two industries to its respective regions are of different strength. Salmon aquaculture was developed on the coast of Norway and has been dependent on the raw material output of such regions. A significant factor for the regional boundness of salmon farming is the specific regulatory system and industry specialization that has led to the path lock-in discussed chapter 5.6. Moving the whole value chain of traditional open pen farming will be a significant undertaking, and only the few regions where ocean salmon farming is viable are candidates for relocation. land-based farming, and to some extent offshore farming on the other hand opens up the industry for relocation as the bond to a regions environmental advantage is broken. The transport cost of salmon is significant and while much of value-added processing is done outside of Norway, due to efficiency and costs reasons, see chapter 4, there are still a regional bond and willingness to bring processing back closer to the production along the coast. The salmon farming industry is still very much bond to a region and is not easily uprooted and placed in another region. The industry DUI knowledge mode, see chapter 2.2, is also difficult to uproot, as it is tacit and not codified, thus very much weaved into the fabric of a region.

cell-based seafood and clean meat on the other hand is an industry that is, at the present state of the industry at least, much less dependent on the specific regional advantages such as production and transport costs. This industry is dependent on acquiring knowledge and capital through communication and collaboration on a global scale where these resources are agglomerated in certain regions dispersed around the world such as the USA, Netherlands, Israel, Singapore and China. It's not to say that there may be a stronger regional attachment as the industry is maturing, but the agnostic inputs (see chapters 4.2 and 6) in the form of low level organic molecules such as amino acids, fat and sugars can be cultivated in a myriad of different organisms around the world, and the production on cell-based seafood, which is to be done in bioreactors can certainly be established in most regions. We can thus conclude that the clean meat, or cell-based industry is less geographical attached to a specific region and can in theory be placed in any geography around the world as the inputs and outputs are in the global scope and the knowledge mode is generally analytical knowledge that is easy to transfer.

As the cell-based seafood industry has much of its roots in the San Francisco region, it is plausible that the global mindset and world leading startup scene has affected the industry into a multi-scalar location (see chapter 2.4). As the industry is a footloose nature, there is also a possibility to break up the value chain over several geographies where certain specific processes can be performed in an optimal location with regional ties to a RIS supporting that type of activity.

Salmon aquaculture activities, however, are mostly aggregated to selected regions, in our case the Bergen region. It can be argued that this is due to its connectedness to the coast where the majority of the world's salmon is produced. This can be defined as regional scale of operations, but it should be noted that many of the corporations have activity in many different geographical locations around the world, but it's almost always connected to a region with comprehensive activity within the seafood sector.

7.3. Knowledge Base & Innovation Mode

The knowledge bases in these two industries have quite a different origin. It is clear from chapter 6, the cell-based seafood analysis, that much of the knowledge is based on research and careful measured experiments conducted by scientists at research institutions. This type of knowledge is very analytical and based on codified knowledge, which is knowledge written down and transferred through mediums such as manuals and instructions and is referred to as an *analytical knowledge base* in the innovation theory, see chapter 2.2. The salmon aquaculture industry on the other hand is more based on knowledge garnered from experience and a hands-on approach, tacit knowledge which is discussed in chapter 5, where much of the knowledge is transferred in a word of mouth fashion and though interacting with the problems. This type of knowledge base is called a *synthetic knowledge base.*

Related to knowledge bases are the concepts of innovation modes. The two modes of innovation discussed in chapter 2.2, STI and DUI, serve as a way to examine how industries are forming new knowledge and interacting with technology and producing innovation results. Firms are mainly either STI or DUI dominant, which again is dependent on the industry practices and knowledge fundament. In our analysis there seems to be a divide between the two industries and their innovation mode.

The aquaculture industry, as discussed in chapter 4.1 is a very practical industry which has also been validated in our interviews: "*They (salmon producers) are focused on production*" (NCE Seafood Informant). Much innovation is of the DUI kind where experience and tacit knowledge is dominating, while there are elements of STI, but this knowledge is often acquired from third party sources such as universities or joint collaboration with research institutions and thus this codified scientific knowledge base is generally only applied to a problem statement but is not actively being developed "in-house" in the industry.

The clean meat industry on the other hand, discussed in chapter 4.2, is very much dependent on a STI mode where much of the research and technology is being developed in-house, as demonstrated from our interviews: "*we've had to do a lot of basic research*" (Finless Foods informant) and "*At Mission Barns we set up a lab, hired a team, started research*" (Mission Barns Informant). Much of the knowledge is codified and gained through experimental development and R&D.

The cell-based seafood industry may have little knowledge exchange with the salmon farmers on the DUI part of producing the product. There is however other surfaces of knowledge exchange, such as the downstream DUI processes that are discussed in the next chapter, and with the satellite industry which has a more STI based approach.

Lastly, it is important to take into account that both industries are not entirely absent of the other type of knowledge base and innovation mode, but often one of the two is dominating. There may also be a connection between the industry development phase and the knowledge base and innovation mode utilized. A nascent industry in a preformation phase may not have a necessary experience pool to draw knowledge from and thus has to utilize codified knowledge learned from analytical sources. As is also discussed in the theory chapter 2.2, a combined STI&DUI mode might be more effective than each separated as it has been shown to lead to greater innovation output (Parrilli & Heras, 2016), which can be seen in some aspects of salmon farming, for example the solutions to the lice problems discussed in chapter 5, are based on a mixture of analytical research from universities mixed with the synthetic experience and engineering in newly established companies to create innovative tools for combating lice.

7.4. Summary of industry comparison

In this chapter I have analyzed RQ3: *What are the differences and similarities between salmon farming and cell-based seafood production?* where two assumptions was made in chapter 1.1.3.

The first assumption made was that: *The production methods of cell-based seafood is significantly different from traditional aquaculture.*

Salmon farming is in a mature state and cell-based seafood is in a nascent state, and other key differences are outlined in Table 2, in chapter 7.1. The multi-scalar geography of the clean meat industry can be argued is a result of the industry not taken hold yet, but fundamentally the industry is not strongly tied to a region and can thus be uprooted by an external shock much easier than an industry tethered to a geography.

The salmon farming industry is reliant on the same basic principles as other animal farming disciplines. Animals, optimized through genetic selection, are fed a controlled diet in a controlled environment to produce animal protein that is processed for human consumption. Clean meat has similar processes but at another scale. Cells, though genetic selection or manipulation, are grown on a controlled growth media in controlled bioreactor environment and then scaffolded and processed for human consumption. While there are similar production pipelines for both products as they fundamentally produce the same product there are large differences in a number of areas such as technology utilized, and expertise needed. The multi-scalar nature of the cell-based seafood industry due to its roots in Silicon Valley and usage of advanced technology are another differentiator from salmon farming which is more of a regional scale.

Cell-based seafood and salmon aquaculture have different knowledge bases that can be argued make the knowledge transfer challenging. Salmon farming with a synthetic knowledge base and DUI way of innovating may not be compatible with the analytical STI ways of cell-based seafood. Due to the limited interactions between the industries it's hard to draw final conclusions but there may be a cognitive distance that will be challenging to bridge in the early stages of interaction, depending on the scientific sophistication of the aquaculture firm.

The Second assumption made was that: *The cell-based seafood production is not geographically tied to a coastal area in the same way as salmon farming and thus has other location preferences*

It is clear from both the literature and interviews that the salmon farming industry is tied to the coastal areas and that Norway has reached the position of the largest exporter of salmon in the world through a mix of crucial beneficial geographical factors that make salmon farming possible but also from the governmental specialization in salmon farming and the specialized regulatory framework that has evolved from the positive lock-in effects of the industry. While there are initiatives such as land-based farming and offshore farming that will change the geographical tether, the interview subjects were confident that open-pen farming would still be the majority production form in the foreseeable future and thus these initiatives are not imminent threats.

Cell-based seafood and clean meat is on the other hand a somewhat more difficult case as the industry is immature and can thus be argued too early for establishment. We can however draw some conclusions from the data collected in this thesis. Clean meat is not tied to a geographical area for production reasons, as the production will take place in closed systems that can be established anywhere in the world theoretically, as long as the required infrastructure such as cell-biology labs, knowledge, capital and skilled labor is present. San Francisco in the USA has been the center of the industry for the last couple of years, but there are governmental backed initiatives and technological hubs around the world that will compete for the clean meat industry. There are areas such as the Netherlands, Israel, China, Japan and Singapore that all have startups, venture capital and/or governmental backing to support the establishment of a clean meat industry cluster in respective region. What would likely happen is that this industry in pre-formation will be split up over multiple geographies when products are on the market and the value chain has started to diverge.

As a summary we can conclude that there are differences in the production processes of firms and the amount of scientific knowledge needed to perform the production which has an impact on the knowledge base and innovation mode of the industries. Cell-based seafood is analytical and driven by an STI innovation mode while salmon aquaculture is more synthetic and driven by a DUI innovation mode. The key actors in each industry is dependent on the knowledge needed to perform their key activities, and thus, as discussed in chapter 5 and 6, the cell-based seafood industry is more heavily populated with startup centric actors while the salmon farming industry is more dependent on large-scale mature firms. cell-based seafood is clearly a multi scalar industry not necessarily attached to a region while salmon aquaculture is more dependent on a coastline that is favorable for salmon farming. Still, the salmon firms have also relations to various collaboration partners internationally.

8. Potential for cell-based seafood in the Bergen region

In this chapter, I will analyze the final fourth research question RQ4: "*What are the enablers and obstacles for renewal of the seafood sector in the Bergen area through cell-based seafood production?*". The first section 8.1 features the data collected through in-depth interviews with key stakeholders in both the cell-based industry and the Norwegian salmon farming industry for this thesis, and the second section 8.2 analyzes the different enabling opportunities for cell-based seafood establishment in Bergen while 8.3 analyzes the disabling obstacles for said establishment. Section 8.4 is a summary and a discussion that will answer the assumptions made under RQ4.

8.1. Opportunities and threats for the Bergen regional innovation system in case of a cell-based seafood industry establishment

The future seafood production may involve cell-based production, aquaculture and other more obscure production methods such as aquaponics: *"I think it's going to be cell-based meats it'll be plant based, it'll be regular meat, most likely it'll be some aquaculture, aquaponics. Like all these things are going to be around. They just have to be way better given the fact, the constraints that our planet is going to be going under the next 20 years"* (IndieBio). Given this situation it is likely that there will be collaboration and competition between the production methods going forward.

The actors in the Bergen salmon farming industry are not familiar with the cell-based seafood industry, which is to be expected from a nascent industry without a proven market that is not present in the region and has significant cognitive distance to the industry. When NCE Seafood are asked if their members are familiar with the clean meat industry: "*No. Completely off the radar [...] their lack of reaction, it's actually reflecting the complete lack of reaction from the market*" (NCE Seafood Informant). cell-based meat is some years away being out on the market. The Hatch Informant notes that the time to market might even be longer than anticipated due to entrepreneurs being biased towards positive outcomes: "*that's just an opinion, I think it probably has a longer time to market than people currently think that are involved, um, and, but that's normal Entrepreneurs are biased towards the positive outcome".* The industry is not established enough to be viewed as a real contender for seafood market shares, and the unknown production cost will affect the market shares: *"it will highly depend on the cost of production in my opinion, how much of a market share can get.*". The time to market also makes it hard to judge if this new industry really will disrupt how we produce seafood today, which is noted by the NCE Seafood Informant: "*But is it because this is a new toy in town or is it really a disruption? If it's a disruption. The disruptive effect is way down the road."* There is also a valid questioning on if the industry will be able to scale up to produce biomass in any significant amounts: "*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.*"

As seafood companies have not seen a tangible product output from the cell-based seafood startups yet, the potential for downstream collaboration (i.e. distribution and marketing) (see chapter 6.5), is as the moment difficult to evaluate: *"If you look at cell-based meat or 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"* (Hatch Informant). When products are on the market, the salmon producers may be more interested to take 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*" (Grieg Seafood informant). There are however potential for cell-based seafood in the region but it will require public funding and dedication from the government: "*If they want to they could just go ahead and establish the global center of cell-based seafood here and it would make sense. Um, but then they would need to drop something like €50 million on that of public money over a few years"* (Hatch Informant). For the salmon farming corporates and their relation to the cell-based seafood industry there seem to be a wait and see approach, where the salmon farmers are keeping track of the developments: "*I think it (cell-based seafood) can become something, but i am still unsure if it is 10 or 30 years in the future [...] personally, my passion is to produce sustainable seafood for the world in the ocean, and this contradicts that, but today we only produce 2% of what we eat from the ocean. I am a bit split on the issue, but we don't want to be naive because at the end of the day, the consumer decides.*" (Grieg Seafood Informant).

8.2. Enabling opportunities for cell-based seafood establishment in Bergen

There is an interest from startups to get access to the knowledge of the large farmers and their animal biology expertise: "*their knowledge of fish embryology, fish genetics would be super helpful*" (Finless Foods Informant). As the fish marking industry has matured, the value chain has diverged into specialized companies occupying specific niches, and thus the genetics companies may be of more interest: "*We have pretty good biotechnology competence though our broodfish production [...] but it's our suppliers that have the expertise on the subject.*" (Grieg Seafood

Informant). Finless Foods do collaborate with fish producers, but none in the Bergen region, as they mainly need the collaboration to get access to tissue samples for their research on bluefin tuna: "*[...] we do collaborate a big fish producer right now. [...] they give us samples, which is huge. [...] we also use their expertise in fish development biology*" (Finless Foods Informant). While the collaboration with the salmon farming corporates may be too early at this stage, Finless Foods see potential in future collaboration: "*[...] 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, who wants fish. They've done all the market research and how fish is bought and sold.*" (Finless Foods Informant).

At this stage there are other areas where collaboration may be more relevant. Almost all activity in the clean meat industry is centered around the companies' research and development that is needed to launch their first products on the market. An environment like this is different from an established industry where the effort are focused on getting costs down, increasing production and solving bottlenecks in the production pipeline, as is more the case for the salmon farming industry: "*The most important thing for us is to maximize the value of what we are doing day-to-day and there all the incentives are primarily to facilitate a good biology. We also see a great potential on the demand-side to increase the growth*" (Grieg Seafood Informant). The focus of the cell-based seafood startups is R&D, so a collaboration with the marine research institutions in Bergen may be of interest: "[...] *scientific the collaboration would be great*" (Finless Foods Informant). There is a strong marine research activity in the Bergen region, and much of the research is at a fundamental level: "*we have actually generated 390 million Norwegian kroner in increased resource funds for aquaculture, for research in Norway and in Europe in general [...] I work with the research, is that what we again called it earlier today "deep science" is the basic aspects of technology or biology, physics*" (NCE Seafood Informant).

An environment like Bergen can be very important for the stage of where cell-based seafood is right now: "*I think that kind of expertise on the fish side of things is hugely important at this stage in the game because there are just so few people in the whole world with fish cell culture experience and the understanding of fish genetics or fish cell biology or fish physiology. And it's just so, it's such a small talent pool and sort of knowledge base*" (GFI Informant).

Norway has a specialized regulatory framework that is adapted to salmon farming, and this framework is driven by sustainability and environmental concerns such as sea lice pressure (see section 4.1.3). A government and regulatory framework that is aligned with sustainability might spill over and become attractive for newly established companies, in terms of support: “*I can definitely envision another place (than San Francisco) that had all the good things and they didn't have the drawbacks, right. There's, there can be a lot more help and cooperation from our government. Alignment from government, which a lot of places will do better*” (New Age Meats Informant). While no official statement on the Norwegian government's stance on clean meat is available, it is plausible to assume that when the industry grows, there will be a positive reaction, due to the sustainability profile of clean meat.

In summary there is required knowledge and expertise in multiple parts of the culture cell-based seafood value chain present in the Bergen region. The strong research environment and animal production expertise is needed by the startups and while some of it is found elsewhere the region is strong and offers a more complete system than anywhere else, and possible governmental alignment would be beneficial for attracting startups to the region. Another important aspect of a location in Bergen is the possible identification as a part of a larger seafood product portfolio which may help with the consumer transition from traditional seafood to cell-based seafood: “*[...] if they (cell-based seafood startups) 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*” (Grieg Seafood Informant). This credibility aspect may be important for the cell-based seafood industry when products are entering the market: *Norway hasn't [...] Iceland, the Faroe Islands, those countries haven't necessarily the image of being science-based craze. They are, they are, they have a good reputation for clean, clean environment good approach to food”* (NCE Seafood Informant).

8.3. Disabling obstacles for cell-based seafood establishment in Bergen

Bergen is a small town on an international scale, with only 280,000 people in the Bergen municipality (Statistics Norway, 2019 B) and 520 000 in the Bergen region (i.e. Hordaland county), with only 280,000 people in the Bergen municipality (SSB, 2019), and this may be an issue for startups: *“For us, having a large international city that has lots of foot traffic is really important. [...] Bergen is good for fish. Um, and outside of Fish like, I don't think a lot of people go there very often.”* (Finless Foods Informant). As Norway is a small country, the domestic market is too small of a target for the cell-based seafood companies, that will have to target large consumer groups to be able to satisfy the scale of which production is needed to be theoretically profitable: "*Personally I think it's good if they (cell-based seafood startups) are closer to market"* (Grieg Seafood Informant).

As discussed in section 5.3 the startup environment in Bergen, while gaining traction from the establishment of accelerators such as Hatch, lack sophisticated venture capital and other sources of risk willing capital which is disabling for startup companies that seek funding and to cluster with similar companies in the early stages. The nascency of the startup environment is also a factor that affects the number of startups present in Bergen. There is an importance of having other startups with a close cognitive proximity for knowledge sharing between the startups as it is important to many of them: *"in terms of people that we really coordinate with closely, it's mostly startups."* (Finless Foods Informant). The few startups available would be a hinder for this kind of low-level collaboration.

The collaboration aspects with the large corporates can be problematic for small companies that easily get "swallowed" by internal processes, which is confirmed by Grieg Seafood Informant when asked how they would collaborate with a cell-based seafood startup in case of acquisition: *"In such an early phase I think one would let them do their own thing not be overridden by the large machines"* (Grieg Seafood Informant).

When it comes to sustainability, or environmental friendly production, the species produced will have an important role in the type of cooperation that will be possible with the salmon corporates: "I *see the potential for (bluefin) tuna, because it's a threatened species and difficult to farm in large-scale. But salmon, there the sustainability challenges are not large enough that salmon from the ocean is impossible, and thus they'd compete more on price there"* (Grieg Seafood Informant).

As the clean meat industry matures, there will likely be more differentiation between production of specific animals, and we can assume that cell-based seafood will be a differentiated industry from cell-based meat. As the industry is still not tied to specific regions, cities like Singapore and Hong Kong have newly established cell-based seafood initiatives,

Bergen may have knowledge on basic marine animal science but there are lacking infrastructure that is needed for a cell-based seafood company: "[...] *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." (Finless Foods informant). As discussed in chapter 5, access to capital is limited for early stage companies in the Bergen region as the innovation infrastructure is relatively immature, and closeness to universities does not necessarily translate to the kind of skilled specialized human resources needed. These shortcomings can be discussed in terms of regional innovation system shortcomings, and is done in the summary chapter, 8.4, below.

8.4. Summary of cell-based seafood potential in the Bergen region

In this chapter I answer the final research question RQ4: *What are the enablers and obstacles for renewal of the seafood sector in the Bergen area through cell-based seafood production?* with the help of two assumptions made in chapter 1.1.4.

The first assumption made under RQ4 was that: T*he strong marine research environment and salmon farming sustainability focus are enablers for cell-based seafood renewal in Bergen.*

We see from the discussion in 8.2. that startups in the clean meat industry is dependent on a RIS with a strong research component, at least at this stage of the industry development. Bergen has a strong marine research environment through institutions such as IMR and UiB. NCE Seafood Innovation cluster acts as a research facilitator for the salmon corporates and coordinate activities where considerable research resources have been deployed. It should be noted that due to the strong degree of industry path lock-in, almost all of the research is centered on salmon farming, and while there are considerable basic research on marine animal physiology, feed optimization, fish health, farming systems and fillet quality, the research can be argued may be affected by the salmon farming synthetic knowledge base and DUI mode of innovation. This means that, as pointed out by Hatch Informant in chapter 5, the focus is very practical and short to medium term in terms of technological innovation. Knowledge transfer from salmon centric research to cell-based seafood may thus not be straight forward, but there certainly are knowledge that is beneficial on the basic research side. Fish health research may be one of the most closely related fields in terms of cognitive proximity due to the similar techniques used, such as in-vitro cell culture and other molecular biological methods and is thus a potentially interesting candidate for cross industry innovation between the two industries.

The next part of the assumption made was that the sustainability focus of the salmon farmers is an important factor for cell-based seafood renewal in Bergen. While salmon farmers are often sustainability focused due to it being one of the main benefits of eating salmon, the sustainability efforts have often, as discussed in chapter 4.1, been driven in a top down approach from governmental regulations such has been the case for the sea lice impact on the wild salmon populations and not been a self-proposed mission for from the industry. There are sustainability driven initiatives from the industry side, such as the Global Salmon Initiative (GSI) that was started by many of the largest stakeholders in salmon aquaculture and is driving sustainable farming as its mission (Global Salmon Initiative, 2019). So, while there are sustainability efforts in the industry and from regulatory bodies, much is centered around salmon and how aquaculture is more sustainable than meat farming. Much of the sustainability enabling will likely be consumer driven, or as one of the salmon farmers puts it: *"If the consumer is adamant that salmon farming in Norwegian fjords not is sustainable, then we or the industry as a whole need to look for new possibilities"* (Grieg Seafood Informant). Thus when the cell-based seafood is more established and if a consumer preference is developed for seafood that is not farmed in the ocean, we can expect that will push salmon farmers to look at cell-based seafood as a potential sustainability opportunity, but at the moment consumers happily accept ocean farmed salmon, as discussed in chapter 5.

The second assumption made was: *The salmon farming industry lock-in and cognitive distance to cell-based seafood are obstacles for cell-based seafood renewal in Bergen.*

The Norwegian aquaculture sector is highly specialized in salmon farming which required a skillset and technology that share similarities with the agriculture and meat producing industries. Cell-based seafood has fundamentally different production techniques and processes which share similarities to pharmaceutical and medicinal industries. Based on the case studies conducted in this master thesis there are limited areas where cross industry innovation between the Norwegian aquaculture sector and the emerging cell-based seafood industry. Most of the potential lies in collaboration in downstream processes such as sales and distribution as well as knowledge transfer with the pharmaceutical companies present in the sector.

The nascency of cell-based seafood and both cognitive and geographical distance to the salmon aquaculture industry in Bergen and its capabilities can be discussed in terms of system failures. In the theory section, chapter 2.3.4., I describe that regions can hinder innovation through various forms of system failures. Four different failures were presented, and below I will extrapolate how these regional innovation system failures affect a potential establishment of cell-based seafood in Bergen.

We start with *capability failures* which refer to the lack of competence in the industry. It can be argued that there are some biotechnological capabilities that may be lacking in the Bergen region when it comes to the establishment of cell-based seafood, as the salmon farming industry often have outsourced some of the processes that are not directly related to salmon farming. There is however strong basic marine animal physiological competence in the Bergen area which is important in the early stages of the industry, but later stage processes such as large-scale bioprocessing, although present in both pharmaceutical and feed sectors of the industry, are not always executed in the Bergen region.

The second failure is *coordination failure*, where knowledge sharing is either too prevalent or lacking, and while this may be a problem for an industry cluster with similar companies, and thus much related knowledge, there are interest organizations such as NCE Seafood Innovation Cluster that provide an arena for salmon farmers and related industries to coordinate their efforts. There are however interaction barriers between the larger salmon corporates and startup companies, as discussed in chapter 5, which may be seen as a coordination failure.

Institutional failure is the hindrance of innovation through regulations, laws and informal rules which can be argued are hindered by the unknown regulatory status of the cell-based industry in the Bergen region. Bergen and Norway follow the same regulatory framework as the European Union, which is a relatively undeveloped regulatory framework compared to the US regulations, as discussed in chapter 4.2.

Finally, *infrastructural failures* encompass the systemic and infrastructural needs for the firms to perform business activities. The Bergen region do have biotechnology infrastructure, but it is mostly tied to research institutions and larger firms and thus challenging to access for earlier stage companies which may be a major hinder for the establishment of cell-based seafood firms in Bergen as they are dependent of such infrastructure, as discussed in chapter 6. The lack of early stage funding infrastructure may be another major hinder for establishment as cell-based seafood is dependent on significant funding to get through the costly R&D processes and production needed to get to market.

9. Summary and conclusion

In this final chapter I will present my main finding, theoretical implications and practical implications of this master thesis.

9.1. Main finding

Below I summarize my main finding through answering the four research questions that have been investigated in this master thesis.

RQ1: What characterizes the salmon industry path in the Bergen region?

The Bergen region are increasingly recognized as the center for aquaculture in Norway, with several of the key firms in the industry located in the region. In addition, the region has a strong marine research milieu. Salmon farming has been a great success for the Bergen region, and through mechanisms such as increasing economic returns, agglomeration economies and cultural-institutional embeddedness a strong positive industry path lock-in has been established, called a stable state. As the industry is dependent on geographical features for open-pen farming such as a long coastline, the industry there is a strong geographical proximity between appropriate production location along the coast and the production of salmon. This geographical link makes for a competitive advantage and barrier to entry for other regions and nations, and thus continuing open-pen farming is in the interest for both the industry and the Norwegian government.

While there are incentives around the world to diverge from the traditional open-pen salmon to scale up the industry such as land-based farming and offshore farming there seem to be a consensus among the interview subjects that open-pen farming will still be dominating in the future. There are certainly research and scientific efforts in the salmon farming industry, but the industry has a synthetic knowledge base and a DUI innovation mode that has been developed by its roots as a farming industry with practical trials and error and not through scientific experiments.

Salmon farming is facing challenges in the form of environmental impact and public perception from propaganda against the industry may be impacting the general perception of the sustainability aspect of salmon farming, but these challenges are not seen by the interview subjects as large enough for consumers to abandon open-pen farming within the next 10-15 years.

RQ2: What is the status of cell-based meat and seafood industry?

Cell-based seafood is an emerging form of seafood production that is in the early pre-formatory state of industry development. The path is characterized by an analytical knowledge pool and STI innovation mode and has a strong connection to research institutions and is accessing knowledge from closely related industries such as life sciences, chemical industries and animal production. The industry can be characterized as multi-scalar, although most activity is centered in San Francisco, there is a significant geographical spread of the industry with firms located in regions all over the world, where location preferences seem to be more associated with willing risk capital.

RQ3: What are the differences and similarities between salmon farming and cell-based seafood production?

Clean meat and cell-based Seafood is in the very early stages of industry establishment while Norwegian salmon farming is a mature industry that needs very little change to stay competitive. Both industries aim to produce seafood for the seafood consumer of the future but utilizes completely different processes and technology to get there, which leads to a significant cognitive distance and establishment of areas of cooperation and competition. There are possibilities of cooperation and cross industry innovation between the two industries are possible in a number of areas, but due to the immaturity of clean meat, we can expect to see very limited cooperation within the next few years but more after that. In a longer perspective, there may be collaboration.

RQ4: What are the enablers and obstacles for renewal of the seafood sector in the Bergen area through cell-based seafood production

The seafood sector in the Bergen region is experiencing a strong specialization in salmon farming, which is the short-term may be positive for competitiveness. The industry is however vulnerable to disruption and will have limited path renewal and path creation potential in incumbent substitute industries such as cell-based seafood. Cell-based seafood is a cognitive distant industry with very different technological origins that nonetheless is set to produce a near identical product. In path dependence theory, new activities and industries from and develop alongside existing industries and can ultimately replace said industries (see chapter 2.3). The emergence of new industries relies on the emergence of capabilities in existing industries in combination with local related or unrelated knowledge.

The most promising areas of cross industry innovation are not necessarily between the salmon farmer and the clean meat industry, but rather with the pharmaceutical companies, feed companies and marine research institutions which have analog niches in the clean meat supply chain that is not currently established.

9.2 Theoretical contributions of this master thesis

Qualitative oriented case studies can contribute toward theory development and can for instance nuance existing theoretical assumptions (George and Bennett 2005). I will argue that my thesis makes two main contributions to existing theory on path development and path creation within EEG.

Much of the work in EEG emphasize the *regional* level when discussing renewal of existing industries and the creation of new industry paths (see chapter 2.4). However, a comprehensive understanding of how new paths are established are lacking. Grillitch et al.2018 differ between development of paths that are new to the region (i.e. path importation) and paths that are new to the world. They argue for a framework that captures the opportunity space for path dynamism and emphasis especially how new industries have knowledge and capabilities that are either related or unrelated to the existing industry structure. Unrelated variety is an important source of the most radical forms of path development, such as the development of paths that are new to the region the establishment of cell-based seafood in the Bergen region is an interesting case for this framework. The difference between the dominant industry path (i.e. salmon farming) and this new path in knowledge bases, innovation modes and technology, discussed in chapter 7, provides a significant source of unrelated variety that could lead to renewal of the seafood sector in the Bergen region. In addition, certain parts of the cell-based seafood value chain and salmon farming are related and will contribute to complementary between these paths (i.e. some of the R&D activity and distribution/marketing). Still, I will argue that Grillitch et al. (2018) does not provide any solid evidence on when path creation will occur and when it will not occur. In my study *I found that the establishment of a path that is new to the region (path importation) is difficult when the dominant path is in a stable state.* High profitability and a stable state mean that this industry will absorb entrepreneurs, investors, technology suppliers and research milieus that otherwise may have been on the lookout for new business possibilities and new sectors to move into.

Secondly, *I also found that industry paths are characterized by different type of geographical embeddedness.* This observation nuances the traditional approach of EEG, where there has been a strong focus on the local or regional embeddedness of industry paths. Some of the critics argue for a stronger focus on the footlooseness of industries (see 2.4). In my study I observed that industries are multi-scalar, but to different extent. Within the salmon industry there is a strong geographical proximity between appropriate production location along the coast and the production of salmon. In addition, the resources of the Bergen RIS are important for the salmon producers. Still, these producers are also linked to research milieus and collaborators internationally and almost all of their production are exported. Cell-based seafood has another type of multi-scalarity. New wave of technology and science driven startups that are dependent of significant cash infusions from venture capitalists to develop their products that may be on the market many years in the future. Knowledge transfer between related startups and closeness to investors may be agglomerating characteristics instead of the traditional costs of goods and transport that originally have described as barriers to footlooseness. While cell-based seafood may look like a footloose industry, it can be argued that San Francisco and similar innovation hubs offer startups infrastructure, capital and knowledge transfer that puts strong incentives for locating in said region, as startups may not survive outside an innovative milieu.

9.3 Practical implication of this master thesis

Finding from my thesis can also inform industry actors and policy makers. cell-based seafood is an interesting new way of producing seafood that can become ethically and environmentally superior while at the same time being food safe while produced in large quantities compared to traditional farming. Granted it does not utilize the regional advantages Norway has for seafood production at the moment, but seafood production untethered from regional advantages may be a future we are heading toward as carbon footprint connected to air transport is a hotly debated issue, and closed systems can keep the production closed from the environment.

Bergen is a strong contender for the early stages of cell-based seafood development due to the advanced marine research that is being done at institutions such as IMR and UiB in Bergen. Our analysis has highlighted the importance of basic research as a fundamental need for the cell-based seafood industry at this nascent stage. There are also emerging research initiatives at Nofima, University of Oslo and Sintef that are within the clean meat scope but have not been discussed as a part of this thesis due to lack of time but are interesting for further research.

The Bergen RIS may however be lacking some of the necessary infrastructure that is needed for cell-based seafood to emerge as an industry path in Bergen. The industry is as is evident in section 4.1, reliant on infrastructure such as regulatory approval and specialized R&D facilities in the form of laboratories and other scientific infrastructure. From informal conversations with key players in the Bergen RIS, there is a consensus that while scientific infrastructure exists in Bergen, it is tied to the research institutions or established pharmaceutical companies. This infrastructure is tailored to the needs of the organization so space capacity may not be available for an emerging initiative. I strongly encourage the establishment of rentable laboratory space that is focused on early stage companies to remedy the lack of infrastructure and accelerate not only cell-based seafood initiatives but also other marine biotech startups as well.

As the salmon farming industry cross-industry innovation potential is somewhat limited due to the low technology and knowledge transfer potential on production, and the future looks stable for salmon farming, there is at the moment little interest in collaborating with cell-based seafood startups. If Norway is to contend with other countries however, there has to be a governmental initiative to specifically facilitate cell-based seafood as a part of the future industrial strategy for the country and support emerging actors with funding and infrastructure support. This is important for developing a more diverse and sustainable seafood sector.

Singapore, China, Japan and other nations are entering into clean meat as a governmental initiative, and the infrastructure and funding opportunities from such top-down pushes will likely impact the establishment of cell-based seafood more than the closeness to strong R&D facilities as funding is such a critical component.

It is important to prepare for the possibility for the seafood production 10-15 years in the future where consumer behavior and sustainability pressures may cause emergent new ways of production that will impact the current open-pen salmon farming market share. Diversifying the current seafood sector will reduce risk in the event of industry-specific shocks in accordance with portfolio theory, that is a plausible outcome if consumer acceptance for ocean farmed salmon turns negative due to current sustainability challenges. An importation of cell-based seafood industry to the Bergen region could also to diversify the knowledge pool by bringing in unrelated and related biotechnological knowledge that may have positive knowledge spillovers to the industries in the region.

9.4. Future research

This master thesis has been an overview of the possibilities for diversifying the seafood sector in Bergen region with a specific focus on the salmon farming and cell-based seafood industries. As the thesis conclude that one of the main areas of knowledge transfer between the two subject industries is in the marine basic research, it may be interesting to focus on what should be the research agenda in the future for the seafood sector, and especially how it can link up to cell-based seafood and other biotechnological industries.

One future research direction that may be worthwhile to investigate is the call-based seafood industry path and salmon aquaculture industry path connections in the light of a global innovation systems framework to better understand the transnational connections that exists due to the geographical distance, which could draw on the multi-scalar investigations made in this thesis to better understand how cross-disciplinary research hubs could be constructed.

As cell based seafood would benefit from establishment in Bergen region due to the advanced marine research, fish health, feed and highly advanced aquaculture industry present, I also would encourage future research on establishing infrastructure and funding support for marine biotechnological early stage companies to be investigated by the current government, as it could lead to sustainable seafood industry path renewal which is in line with Norway’s current trajectory as a world leading producer of 5 million tonnes of healthy sustainable seafood by 2050. Such research could uncover where the main bottlenecks for early-stage companies are and how we can ensure more effective commercialization of relevant research findings.

9.5 Limitations

In this final chapter I want to address some of the weaknesses in the analysis and data collection of this master thesis.

First off, my involvement in both industries through personal entrepreneurial activities may have affected the thesis with a selection bias by subjects being chosen through convenience and personal relation rather than a strictly objective reasoning.

Secondly, due to time constraints, the significant number of informal interviews I have conducted for personal reasons have not been thoroughly included in the empirical data, which if included could have assisted in increasing the validity of the in-depth interviews. Another option in increase the validity of the in-depth interviews might have been to have a more rigid interview guide.

Third, adding a marine research institution and a pharmaceutical company as well as subjects from the emerging research initiatives at Nofima, University of Oslo and Sintef to the interview subjects may have yielded a better dataset for the specific areas of analytical knowledge transfer between the two industries Finally, adding co-researcher to the thesis would have been a sensible strategy for remedying the time constraint and possibly selection bias though acting as a third party.

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Appendix

Appendix 1. Interview Guide

General

- How did you get into this industry and what's the history of your company? What is its inspiration and origin?
- Describe your industry and the other companies present in the industry. What is specific about your company?
- Where are you and your staff from originally?
- What people are currently in the organization and what talent are you looking for?
- Can you describe your business units?
- Where do you operate from and how centralized is the organization?
- Are you present in other regions and countries? What processes are happening elsewhere?
- Do you have any spin-off companies?
- What is driving the clean meat and aquaculture growth?
- Why are consumers, startups and investors so interested in these industries right now?
- Would you say you know the general consensus of your industry? Can you speak for the industry? IE is there a large spread in opinion in various subjects or are the challenges and opportunities apparent for everyone.
- What people are currently in the organization and what talent are you looking for?
- Do you believe clean meat will continue in the same trajectory? How will it evolve?
- How capital intensive is the industry
- Will there be competition between ordinary and clean meat or is it positioned as its own product category? Is it a substitute?
- What made you decide to operate the company from where you are now, and do you think the location of the company might change or become more dispersed?
- What people are currently in the organization and what talent are you looking for?
- What industries are you collaborating with?
- What bottlenecks are you facing?
- Do you think we will see a split where aquaculture and cell-based seafood is being done in separate places, as it is done today?
- What technologies and processes from aquaculture do you think cultured meat could implement to accelerate the industry? And vice-versa
- What is the natural place for cell-based seafood, niche product?

- Is cell-based seafood a natural successor to aquaculture, and do you think that the salmon corporates are well equipped to move into this new industry?

Tech/Biotech

- How much biotechnology does your company do in house, and how much is outsourced?
- What kind of biotechnology companies do you engage with?
- What kind of basic research do you conduct? Genome sequencing, cell morphology characterization? Cell breeding?
- Are you using fermenters and bioreactors?
- How did you get to where you are today?
- Could a reorganization of the aquaculture system result in the clean meat industry or is there too much invested in specialized equipment to adapt?
- Is the equipment easy to sell or retrofit to something else?
- Who is owning the equipment?

Innovation

- Describe your last innovation, what was the bottlenecks, what worked?
- What are the critical factors for being innovative? Is the market, technology or what are the blocking mechanisms for innovation?
- Innovation loop how quickly do you iterate product development. Production time. Produce lifetime in market? Can you be outcompeted by new incumbents?
- How would you describe the organizational structure, how is innovation work structured? How is development of product organized.
- Bottom up / top down, how is innovation materialized?
- Do you look for innovations, knowledges and tech from other industries? What industries are you collaborating with?
- Do you look for innovations in other industries?

Region / EEG

- Are you present in other regions and countries? What processes are happening elsewhere?
- Would you say that you are only active in the clean meat industry?
- What made you decide to operate the company from where you are now, and do you think the location of the company might change or become more dispersed?
- Why are you spread out over many locations?
- Why have you decided not to locate in Norway?
- Do you think the clean meat industry could have cropped up anywhere else or is this environment special?
- How is this moment in time affecting this industry in the region, have there been any changes in how institutions, consumers etc. behave?

San Francisco specific questions

- If you had a salmon corporation as an owner, how would that theoretically affect your operations?
- During your time in the clean meat industry, has the landscape changed much? What institutions are involved?
- What is your relation to the aquaculture industry?

- Do you collaborate or do you plan to collaborate with aquaculture?
- What parts of the aquaculture industry, what kind of actors?
- What specific knowledge and technologies in aquaculture do you think you can use
- Distribution marketing? Same way other ways?
- Where are the costs of clean meat, how much is allocated towards R&D?
- Who are the investors in seafood clean meat, anyone from the aquaculture industry?

Bergen specific questions

- Is the biotech scene strong enough in Bergen for cell based seafood to be established here
- Is Bergen still a center or the center for aquaculture? Is that set to change?
- Describe knowledge transfer between startups. What kind of info?
- Describe knowledge transfer between salmon farmers. What kind of info?
- Describe knowledge transfer between startups and salmon farmers. What kind of info?
- Have you heard the aquaculture industry mention clean meat / cultured meat in ny setting and if so, was it a producer, supplier or other kind of company?
- Do you think the clean meat industry could have cropped up anywhere else or is this environment special?