Universitetet
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UNIVERSITY OF STAVANGER BUSINESS SCHOOL
MASTER'S THESIS

STUDY PROGRAMME:	THIS THESIS HAS BEEN WRITTEN WITHIN THE FOLLOWING FIELD OF SPECIALIZATION:
Master of Science in Business Administration	**Economic Analysis** IS THE THESIS CONFIDENTIAL? **No**

TITLE:

Climate Risk in Norwegian Aquaculture

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Abstract

Climate change poses significant challenges on a global scale, and financial impacts could be caused both directly through natural disaster and indirectly through a transition to a lower-carbon economy. Climate change and global initiative force adjustments, which makes climate-related risks and opportunities applicable to all sectors and industries. This highlights the importance of incorporating risk assessment, and risk management into companies' long-term strategies to reduce risks.

This thesis aims to improve the understanding of how climate risks and opportunities affect the Norwegian aquaculture sector. More specifically we utilize the Task Force on Climate-related Financial Disclosure's framework to identify climate-related risks and opportunities. Previously written literature and microeconomic models combined with value chain methodology enable us to anticipate the implications for the sector.

Our findings suggest that transition risks are the most critical in the short- to medium term. They include expected policy changes, and regulations surrounding feed scarcity and sustainability. Price sensitivity of raw materials due to their large share of total costs combined with the vulnerability to climate risk indicate that the feed-market is the primary concern for sustainable development. Further we find that physical climate risks may become a challenge in the long run, however the implications are hard to estimate. Opportunities are mainly presented through future growth potentials, and collaboration within the sector.

Acknowledgements

This thesis completes our Master of Science (M.Sc.) in Business Administration at the University of Stavanger. Our courses, personal interests and relevance makes climate risk a natural choice for our thesis. We want to broaden the understanding of financial implications of climate change in general, and specifically for the aquaculture sector. Additionally, we hope that our research may help businesses within the sector to prepare for the financial implications.

The process has been demanding and interesting, due to limited prior knowledge around climate risk in aquaculture. Throughout the process we have developed knowledge on how to apply economic theory and risk management to a complex challenge such as climate change. The knowledge and methods are versatile, meaning they can easily be applied to other sectors making the knowledge highly relevant in today's changing economic situation.

We would like to use this opportunity to extend our appreciation and gratitude towards our supervisor Klaus Mohn, who has been a valuable source of guidance and motivation throughout the process.

Malin Friestad
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Stavanger, 15.06.2018

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1. Introduction

1.1 Background and Motivation

Climate change is one of the first externalities we face on a global scale, and therefore an issue that needs global recognition and effort to overcome. The inherently complex nature of climate change makes the future uncertain, as impacts and scope is less clear. There are global initiatives to curb carbon emissions, which means that countries all around the world has started to design and implement low emission developments strategies. The goal is to shift to a lower-carbon economy, and the transition would require a long-run view with change in behavior of governments, financial market participants, companies and consumers.

The long-term nature of climate change makes economic decision- making challenging as decisions taken today do not necessarily consider the long-term implications of climate change. Furthermore, climate change also causes near-term financial impacts, as global initiatives has forced the transition to a low-carbon economy to accelerate. This transition affects all sectors and industries, and present significant risks. It could also create opportunities for those that manage to adapt to the transition. Because of the near-term challenges this shift pose, climate-related risks and opportunities should be incorporated into companies' risk management assessments and be considered in their long-term strategy.

Since the oil and gas industry plays an important role for the Norwegian mainland economy, a slowdown in this sector would increase the need for innovation in both existing and new industries, as well as increased entrepreneurship initiative. Large sea and coastal areas have made Norway suitable for other offshore- production, such as fisheries and seafood farming, and aquaculture production started back in the 1960s. Due to stable temperatures, sheltered sites, slow maturing of salmon/trout and governmental support, the Norwegian aquaculture has experienced success. Aquaculture production has grown steadily since it started, and traditional capture fisheries have almost flattened out. Today almost all seafood produced in Norway is exported, and seafood export is the second largest exported good after oil and gas. Since seafood production became industrialized the global demand for seafood has rapidly increased and are likely to increase due to a growing global population.

As aquaculture plays a significant role for the Norwegian economy and is still a growing sector, it became natural for us to aim our study on this particular industry. Fish farming is not necessarily an industry associated with climate risk, as opposed to the oil and gas industry. Even so, our choice of industry made us able to show that climate-related risks and opportunities exist for all industries and sectors. The ambition of this thesis is to uncover both climate- related risks and opportunities faced by the aquaculture sector. Where climate-related risks cover both risks related to the transition to a lower-carbon economy, and risks that arises directly from climate change. Further we would like to analyze the implications of these risks both for markets within the sector, and for the sector as a whole. By doing so, we hope that we could increase awareness of the financial implications for the sector and provide insight as to how these implications might affect the future of the sector. The target group for this thesis is in that respect the companies throughout the aquaculture value-chain, and the governing institutions that construct the policies and regulations the sector faces.

1.2 Research Question

Which climate-related risks and opportunities do the Norwegian aquaculture face, and what are their financial implications?

1.3 Research Method

Our thesis is based on the recommendations from The Task Force on Climate-related Financial Disclosures (TCFD), which is a report aimed to help participant of the financial market and industries to understand climate-related risks and opportunities, together with their financial implications. We have constructed our thesis around the same framework as the TCFD represent in their recommendation, as illustrated in figure 1.

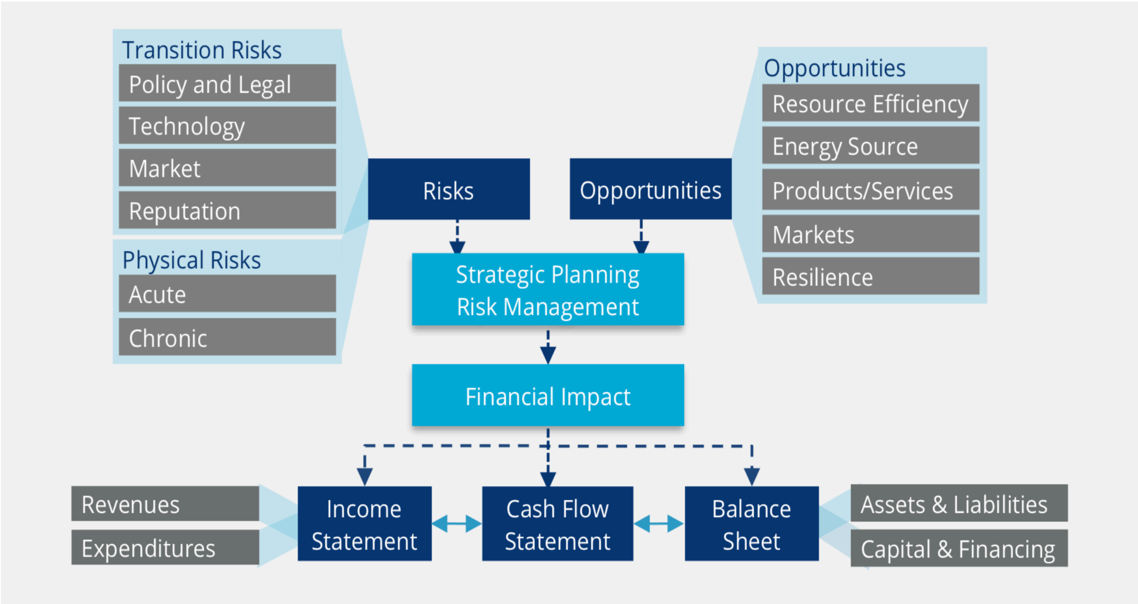

Figure 1: Climate-related Risks and Opportunities and their Financial Impact (TCFD, 2017)

Physical risks are physical impacts from climate change and is divided into acute risk and chronic risk. Transition risks refers to the transitioning to a low-carbon economy, which concerns policy and legal-, technology-, market- and reputation risks. The recommendation from the Task Force is mainly focused on how organizations across sectors and industries can disclose climate-related issues to financial institutions, where the goal is to prevent financial instability caused by climate change. The analysis itself is divided into markets, where we examine climate-related risks and opportunities in the input markets, i.e. feed- and labor market, and how these risks and opportunities potentially could affect the output, i.e. product market. We have also applied microeconomic theory to fully understand the mechanisms of changes in prices, supply and demand. Further, we used economic theory about uncertainty and investment behavior to understand how uncertainty in price-, demand-, and supply changes could affect the investments of the industry.

1.4 Limitations

In order to make the analysis more focused and clear we primarily focused on aquaculture of salmon and trout. Since the vast majority of aquaculture production in Norway consists of these species, this seemed acceptable. Through the thesis we have utilized the TCFD framework, however we have not covered legal transition risk. Legal issues might become a concern; however, they will not be covered in this thesis.

1.5 Disposition

This thesis consists of five chapters. The first chapter provides an overview of risk theory, and how uncertainty could be incorporated into economic theory. The objective of this part is to get an understanding on how uncertainty could affect investments behavior, which is relevant due to the uncertainty with climate change and climate-related risks. In this section, we also give a small explanation of the importance with risk management, and what it involves. In chapter two, we describe why climate risks has become such a relevant term and explains how sectors and industries could identify and assess the potential risks and opportunities that they face. The third chapter gives an introduction of the sector, including reasons for development, and growth through the years. Further it brings forth the value chain and the processes involved in aquaculture production. In chapter four we utilize the knowledge from "climate risk" to identify both the climate related opportunities and risks the sector face as a whole. This is done by first identifying the opportunities, and then the physical and transition risks. The last chapter analyze the financial implications of the climate risks and opportunities identified in previous chapters, along with recommendations for the actors within the sector.

2. Risk

When talking about risk in a daily manner, we frequently think of bad outcomes. From a business perspective, risk is often associated with negative events causing distractions to reaching a goal (i.e. negative impact on finances, reputation, infrastructure or marketplace). Normally, people do not like to make decisions that can affect them negatively, in other words, individuals do not seek risk and are more likely to be risk averse (see Binswanger, 1980). Investment behavior among firms also depend on their degree of risk aversion (see Bo & Sterken, 2007). A previous study done by Kumbhakar and Tveterås (2003), showed that risk aversion also applies to salmon farmers. In aquaculture, especially in salmon farming, risk exists related to the production process which implies that the risk aversion can be explained through investments made related to capital and labor. Nevertheless, risks must not only be associated with negative outcomes; if the reward is big enough individuals and organizations have the tendency to choose strategies that involves high risks (Hopkin, 2013).

In finance, we consider both "upside "- and "downside" risk, both danger and opportunity (Damodaran, 2012). However, it is important to emphasize that resilience could make a business able to take advantages of events that is primarily unwelcome. Carbon emission trading could be an example. If the business is cost-competitive, as well as easily able to reduce their carbon footprint; the perceived "downside" risk, can be turned into "upside" risk, by being able to sell their carbon quotas to businesses that cannot easily reduce their carbon emissions. Kumbhhakar and Tveterås (2003) also found that Norwegian salmon farmers have the tendency to be risk averse when it comes to downside risks. This behavior often implies that they avoid situations that are risky, although it could give them potential gains. However, the thought of risks being something negative or unwelcome is often the starting point of evaluating, consider, measure, and manage risk (Hopkin, 2013).

2.1 Uncertainty, Risk and Ambiguity

Decision-making often contains some degree of uncertainty, which means that the decisions are optimal given the uncertainty. Uncertainty means that there exists lack of information about all possible outcomes or events, as well as their consequence, magnitude and/or severity. When talking about uncertainty, we often divide it into uncertainty referred to risk and uncertainty referred to ambiguity. Uncertainty referred to risk is present when it exists statistical possibilities of multiple outcomes, while uncertainty referred to ambiguity is present when probabilities of multiple outcomes are unknown or not well-defined (Huettel et al., 2006). This paper aims to analyze climate risk in the aquaculture sector, however climate change seems to involve most industries in the economy, indicating that the uncertainty related to climate change (i.e. climate risk) is affecting most companies.

The complex nature of climate change makes it hard to understand what the impacts will be, as well as when and where they might occur. Climate change is happening, but the circumstances around the phenomenon and future events caused by climate change are difficult to predict with certainty. Scientists have collected observational data of temperature changes and increasing sea level over many years. However, the consequences have not been as well established when the estimates contain various degrees of uncertainty (Weber et.al. 2011). Future challenges related to climate change are uncertain, but important to embrace. For this reason, both individuals and firms must take the unknown into account in decision-making to avoid critically wrong choices. We are therefore going to give a general presentation on how climate change, and its uncertainty, may affect the aquaculture sector including product market, feed market, labor market and investments - as this reflects how the companies respond and adapt to climate change.

It could be argued that the aquaculture sector is vulnerable to climate change. Aquaculture production relies on the aquatic environment, which implies that sea temperature and extreme weather conditions make the production risky. At the same time, would the production process also affects the aquatic environment and the biodiversity negatively in the geographical area it operates in (e.g. fish diseases, lice, organic emissions and habitat loss). Monitoring is therefore essential in sustaining fish welfare and plays an important role when it comes to risk management. Suitable equipment and competent employees is therefore necessary when preventing biophysical shocks such fish lice and other diseases. Since aquaculture is a biological production process dependent on the aquatic environment, there exist uncertainty related to the externalities caused by the sector. Externalities in this study refer to consequences production activities from the aquaculture causes a third party. Third party means other interests and users of the environment. Examples of externalities are illustrated in figure 2. In order to balance protection of the environment and stakeholders interest, appropriate regulations and policies are needed, which makes them a candidate for government regulations (Osmundsen et al., 2017).

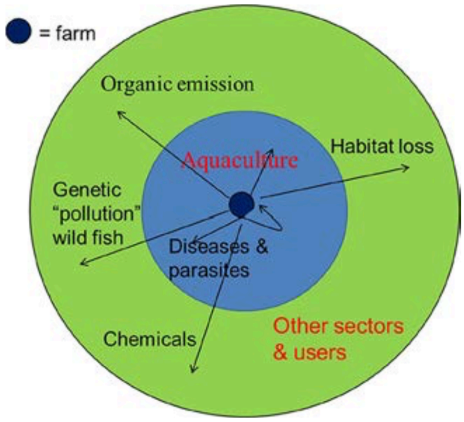

Figure 2: Externalities from Aquaculture (Osmundsen et al., 2017)

2.2 Risk Perception and Risk Behavior

In decision-making people and firms try to collect as much relevant information as possible about the statistical distribution of different outcomes. However, under uncertainty humans often allocate subjective judgements of the probabilities of events, which means that human perception of risk is a mental construct (Sjöberg, 1979). Previous studies have shown that under subjective expected utility theory the decisions taken by an individual do not only depend on their attitude towards risk, but also their strength of belief regarding the probability of the outcome (Savage, 1972). This indicates that decisions taken under uncertainty often do not correspond with the true probabilities of the outcome.

Studies of climate change has often been presented in statistical terms using historical data (e.g. temperature changes and rising sea levels), which means that the issue has mostly been communicated in analytical formats (Van der Linden et al., 2015). However, a person's strength of belief is not only dependent on empirical considerations, but also experience related to the issue affect human judgement and decision-making (Sjöberg, 1979). Nevertheless, studies have shown that people has noticed changes in their local climate and relate this experience to the perception of climate change (see; Akerlof et al., 2013). To tackle climate change there is need for both natural science and social science. Humans' perception and behavior towards risk is of importance as it gives us indications on how to facilitate efficient strategies to reach international, national and organizational climate targets. Risk perception is the degree to which the actors feel that they could be affected by the change, and adaptive capacity is what they feel they can do in response to the change. "This process can be seen as a case of nominal/actual value comparison: the bigger the difference between the nominal value (what a person wants to happen or not to happen) and the actual value (what a person expects to happen), the more motivation or 'energy' is released for adaptation." (Grothman & Patt, 2005).

How uncertainty affects the behavior of agents is important as it may lead to underestimation or overestimation of outcomes, which again could lead to inefficient investments. In relation to climate change, this could mean that a company or industry fail to adapt to the lower-carbon economy. Risk can also be viewed different by actors involved. From the investors perspective, each individual firm is only a small portion of the total portfolio, whereas from the managers' perspective, the risk might be significant (Damodaran, 2012). This has applications for how the risk is managed, from an investor point of view it might be best to transfer the investment to another firm or sector in order to get the highest returns and avoid losses. From the managers point of view this is rarely an alternative. They have to evaluate the options for lowering the costs or increase revenue in order to increase the profit. This is important in order to be able to stay afloat, pay the employees, but also in order to keep their investors and position in the market. "The objective in corporate finance is the maximization of firm value and stock price. If we want to stay true to this objective, we have to consider the viewpoint of those who set the stock prices, and they are the marginal investors." (Damodaran, 2012, p.83). This means that when we study risk from the perspective of aquaculture sector, we need to be objective when evaluating whether the risks are positive or negative for the value of the company, and the effects on the sector in general.

Since uncertainty affect decision-making and investment behavior, it is necessary to investigate previous studies on the area. It has been a lot of discussion on whether uncertainty results in an increase or decrease in investments. Some previous research has shown that increased price-, demand- and cost- uncertainty do not decrease current investments, but might increase it (see Hartman, 1972; Abel, 1983). This would require that the marginal product of capital in a competitive firm is convex in price, such that an increase in the variance of price raises expected return on marginal unit of capital and thereby the attractiveness of the investment (Carruth et al., 2000). Other authors have argued that increased uncertainty leads to postponement, which is reasonable as information comes with time and people prefer to delay investments decisions to await the arrival of new information. Current investments would therefore decrease due to the option of delay (See Bernanke, 1983; McDonald & Siegel 1986). Traditional investment calculation such as net present value

(NPV) does not consider other options. When using the NPV calculation, we value projects by the expected value and if a project has a positive net present value, it is carried out. NPV therefore only consider whether to invest or not. This implies that the model does not explain uncertainty and how it affects investment behavior, such as the option to wait or opportunities carried out after an investment is taken. We are therefore going to represent two economic methods related to investments, net present value and real option theory.

2.3 How to Incorporate Uncertainty, Risk Perception and Behavior into Economic Theory

In decision-making individuals prefer known probabilities rather than ambiguous probabilities, as unknown probabilities make the expected utility of options incalculable, consequently ambiguity poses a challenge for neoclassical microeconomics as it sometimes contradicts with expected utility theory (see Becker & Brownson, 1964; Huettel et al., 2006, Portelli, 2013). When considering environmental decision-making from a firm's perspective the most common approaches used are optimization models, such as cost-minimizing and profit-maximization analysis.

Efficient climate policies could tilt customers and organizations behavior towards low-carbon activities, which again could lead to shift in preferences, thereby shift in future prices and demand (Nordhaus, 2013). This would eventually cause changes in production and investments for firms across the sectors. From a business perspective, the neoclassical investment rule - expected net present value, has been the main model used to calculate value of investments. The model considers expected future cash inflows and cash outflows over the project's lifetime $E(CF_t)$, in relation to the initial investments cost (I). The cash flow is discounted with a discount rate to determine the present value of a future cash flow. The rule says that if the net present value is positive (i.e. the generated earning exceeds the anticipated costs) the project or investment would be profitable and should be carry out. The formula is written as;

(1)

$$NPV = -I + \sum_{t=1}^{T} \frac{E(CF_t)}{(1+r)^t} \text{, where}$$

$$CF_t = p_t * y_t - w_t * x_t$$

To understand how climate change, hence climate risk and opportunities, could affect investment decision, we simplify annual cash flow; Where annual cash flow (CF_t) consist of the difference between cash inflows and cash outflows. The annual cash inflows are given as price (p_t) multiplied with production (y_t), while annual cash outflows are given as price of input factors (w_t) multiplied with consumption of input factors (x_t). This simplification is useful in our analysis, as we are going to explain how the different risks identified possibly can affect investment behavior in the sector. With respect to uncertainty, there are several adjustments that could be incorporated in this model, for example; Adjusting the annual cash flow, increasing the discount rate or compounding risk premium with risk free rate – commonly known as the capital asset pricing model. The two last approaches mentioned, lowers the net present value showing that risk reduces attractiveness of the investment. Additionally, comparing different outcomes of cash flows (i.e. pessimistic vs. optimistic) or estimating the coefficient of variation (i.e. determine the risk-return of the investment) are methods on how to incorporate risks (e.g. climate risk) into the valuation (Gaspars-Wieloch, 2017).

Information develops over time and since new information often change behavior around investments people do have the tendency to put decisions on hold in the attempt to reduce uncertainty. When a company decides to invest rather than waiting for new information to arrive, the company gives up the possibility of waiting. Since investments are partially or completely irreversible, the option to wait is an opportunity cost which should be calculated in the cost of investment. Consequently, uncertainty around the outcomes of an irreversible investment results in a decrease in the attractiveness of the investment. Dixit and Pindyck (1994) argue that investments are more sensitive to uncertainty related to market conditions than regulations and policies. NPV tells whether to invest or not, but do not consider the value of other opportunities, neither the value of postponement. Based on these constraints, the second method we present is real option theory, which opposed to NPV analysis considers future opportunities created by the initial investment, thus increasing flexibility. Real option theory is based on the theory of financial options, where an option is a contract-based agreement that gives the privilege, but not obligation, to either sell (put) or buy (call) a commodity or security to a set price within a given time in the future. Real option on the other hand is not a financial instrument, but share the same mindset, where a real option gives the privilege, but not obligation, to undertake a certain business initiative. For the aquaculture sector, business initiatives could be vertical integrations, new production areas, expansion of pens or to invest in capital such as transport modes.

2.4 Risk Management

The experience of financial instability during the financial crisis has changed investor's attitude towards risks, as well as done organization's more aware of the need for risk measures that could deal with rare/extreme events (Mertzanis, 2013). The focus on risk management and investors behavior has therefore got an increased attention from organization after the financial crisis. Mark Carney, the Governor of the Bank of England, argue that climate change is now a major threat to the global financial stability, which highlight the importance of controlling climate change as one of the major risk in organizations (Carney, 2015).

"Risk management is about achieving the best possible outcome for the organization by preventing negative events, minimizing the damage done by these events when they occur and containing the costs after the event" (Hopkin, 2013, p.3). In the book "Risk management", the author Hopkin (2013) has represented a guideline of implementing risk management, which is based on five different components.

1. Risk agenda
2. Risk assessment
3. Risk response
4. Risk communication
5. Risk governance

The first thing organizations should think about is what they are trying to achieve through risk management, which means setting up a risk agenda. The first component is given the organization the ability to understand why they should undertake risk management activities by looking at events that might affect the organization in the future. The second components, risk assessment, is about evaluating or analyzing the likelihood of each identified risks and thereby identify potential consequences if they should occur. What is the potential impact of those risks that has been identified on finances, reputation, infrastructure and marketplace? And what is the consequences for strategy, tactics, operations and compliance?

The third component, risk response, is about figuring out what the organization should do about those risks that matters. The organization should develop a plan on how to respond to the risk through minimizing the impact, adapt to it, or to avoid the problem; Terminate, treat, transfer or tolerate. This would require controls, recovery plans and business continuity plans. This component of risk management enables the organization to assess the required resilience of operations by having a clear plan of action.

After setting risk action plans, there should be created rules and procedures that all within an organization are familiar with, hence everyone should know their roles and responsibilities related to the action plan that has been created. Risk communication should enable the organization to have a good reporting system and include risk performance indicators which monitor their plans of action. It is however important to remember that existing risks develops and that new risks emerges, which indicates that risk management is a continuous management process. Action plans, reporting systems and monitoring instruments should constantly be updated. Climate- related risks do for example have and growing role in risk management these days. As described we can see that this component concerned internal risk communication, but it is also important to mention that this component should also contain external risk communication.

Each organization has a range of stakeholders, investors that is interested in organizations' profit, customers that is interested in product and service, society that is interested in ethical operations, regulators controls that operations are following laws and regulations and so on. Different stakeholders would also have different expectations to the organization. Therefore, it would be important to identify the range of stakeholders, different expectations among those stakeholders and evaluate conflicting expectations. Related to risk management, organizations should identify, control and monitor risks that can cause failure to maintain stakeholders' expectations, as well as report this to their stakeholders.

Financiers plays a key role in economies as they are deciding which company to invest in, or who to lend to. In this kind of decision making, information would play a crucial role in order to get the highest possible yield and to avoid losses (Jortveit, 2017). Organizations should provide assurance to their key stakeholders, which means developing report arrangements and governance procedures on how to manage existing risk and emerging risks. This is the last step of the risk management components, risk governance. Since the world is in constant change, risk management is a process where an organization frequently search for risk that they must face.

3. Climate Risk

Climate change might be the first real economic externality we face on a global scale. It is different from other externalities in four distinct aspects; (1) it occurs on a global scale; (2) some of the affects are long term; (3) a significant deal of uncertainty around the consequences; (4) the effects might be severe and permanent (Stern, 2008). Assessing the impacts of global warming is a complex problem, as there exists uncertainties about the degree of future climate change and the subsequent impact on global activity. To prevent continued emission of greenhouse gases, which are the dominant cause of global warming, countries around the world has started to design and implement low emission development strategies. Due to the transition to a lower-carbon economy, climate-related risks have become a highly relevant term for decision makers and covers both climate change and climate policies (Norwegian Climate Foundation, 2017).

Financial instability can be derived from both physical implications of climate change, and society's response, as it may interrupt pricing and allocation of assets and capital. The transition to a lower-carbon economy force companies to adapt, and financial institutions to increase their demand for access to risk information regarding climate change. In response, Task Force on Climate-related Financial Disclosures was established by the Financial Stability board (FSB) to give a recommendation to help participant of the financial market to understand their climate-related risks (see TCFD, 2017). FSB is an international organization that was established after the G20 London Summit in 2009, in order to promote financial stability through recommendations about the global financial system (FSB, w.y)

The Task Force's recommendation is based on the Governor of the Bank of England, Mark Carney's (2015) speech "Breaking the tragedy of the horizon – climate change and financial stability". Where Carney highlight the importance of climate-related disclosure and divides climate risk into two categories, physical risks and transition risks.

3.1 Climate-related Physical Risks

Physical risks arise directly from climate change, such as climate and weather events. In the report, TCFD splits physical risks into acute risks and chronic risks. Acute risks refer to adverse events that suddenly occurs in a relative short time and creates substantial losses or disruption. Examples can be such as floods, cyclones and hurricanes. Chronic risks are shifts in climate patterns in the longer run, such as higher temperatures in air and sea, which again cause rise in sea level and chronic heat waves. Both acute and chronic risks can cause damage on property and assets, as well as affect organizations indirectly through disruption in trade. An example of disruption in trade could be adverse events causing disruption in an organization's supply chain (i.e. flood causing difficulties for transportation).

3.2 Climate-related Transition Risks

3.2.1 Policy and Legal

Climate policies aims to reduce the negative effects of climate change or by adapting to climate change, indicating that legal risks that companies' faces are failure to adapt to climate change, mitigate impacts, or inadequate information around financial risks due to these climate policies. One example of policy risk is carbon pricing. Tradable quotas or a pigovian tax on emissions are examples. A pigovian tax would increase the per unit cost of production

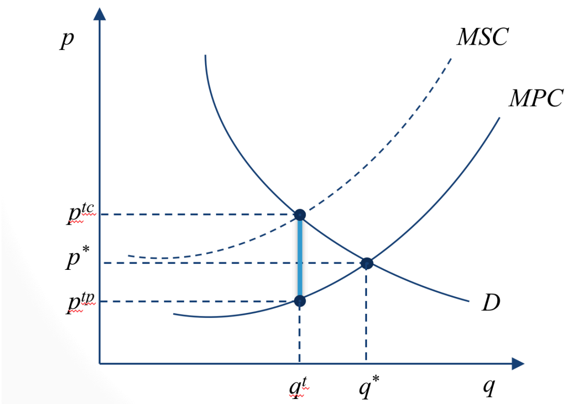

Figure 3: Pigovian tax on greenhouse gas emissions

in an effort to include the societal cost of pollution to the cost of production. In figure 3, we can see that a pigovian tax (bold blue line) would increase the price for the consumer (p^{tc}), and decrease the quantity produced (q^t), and decrease the price for the producer (p^{tp}). The idea is that the tax should reflect the cost of future pollution, and that the producers should have to pay for these costs, and that a higher price would decrease quantity demanded, and reduce future investments. For the aquaculture sector, this will mainly affect the production of feed and the transportation of fish, which we will return to later.

3.2.2 Technology

The intention to curb carbon emissions involves technological solutions that could help the transition, and the technological development could therefore have a significant impact on industries. The adaption would among other things include substitution of existing product and services, and investments in new technologies. Technological risks include unsuccessful investments in new technologies and cost of transition to lower emission technology. But development in emerging technologies and implementation of processes would be important to prevent major financial impacts, as failure to mitigate or adapt to the technological shift potentially could cause wider implications than the adaption itself.

3.2.3 Market Risk

Climate change can change markets in varied and complicated ways. Shifts in demand and supply are one of them and may impact both the producers and the consumers. One example of such a risk is the palm oil industry. Palm oil with its wide application due to cost and attributes, has become one of the most widely used vegetable oils. On the positive side it gives jobs to the poor, helps with the food crisis and at the same time provides biofuel for vehicles. On the other hand, the areas used for palm oil production leads to deforestation of the rainforest and CO2 emissions (Mohd Noor et al., 2017). As consumer awareness has increased, many big producers such as Nestle, and Unilever have been forced to buy from responsible suppliers, in order to reduce deforestation. This is an example of the power of enlightened consumers, and their power through demand (Datamonitor, 2010). The case study further points to the fact that consumers are becoming more powerful due to the use of social media and digital communication.

3.2.4 Reputational Risk

Reputation risk are risks associated with consumers perception of an organization’s contribution or detraction from a transition to a lower-carbon economy. In order to show the consumers that the firms are respecting their concerns, certifications are a helpful tool. There are certifications for most aspects of the operations. Healthy work environment, reduced pollution and impact on nature. Certifications work in such a way that a third party assesses the conditions of productions and evaluated the sustainability. This could lead to loss of transparency and tractability. Products can be hard to trace back to a single supplier due to small suppliers, and complicated value chains; hence it is hard to evaluate the effectiveness of the certifications (Mohd Noor et al., 2017) Potentially this could lead to corruption, and a sense of false safety for the consumers. (Jahn et al., 2004)

3.3 Climate-Related Opportunities

Those organizations that are resilient and prepared to manage climate change and climate-related risks obtains a competitive advantage. Even though there are several potential negative risks associated with climate change, there are also potential lucrative opportunities created for some organizations. The Task Force presents five aspects that can create opportunities for an organization:

3.3.1 Resource Efficiency

Due to technological improvements, there has been and will be an increase in resource efficiency. This means that organizations can provide same service/product using less resources. The technological improvements create the ability to increase production and still use less resources, distribute more efficiently due to improved information flow, use less energy to provide the same service and to use less carbon intensive building materials. By improving resource efficiency throughout their supply chain, organizations can successfully reduce operating cost while they contribute to the efforts to curb emissions.

3.3.2 Energy Source

Further there will be more focus on renewable and low-emission energy sources to meet the energy demand, whilst staying below the 2-degree target (IEA, 2017). Organizations that shift towards low emission energy can potentially save annual energy costs because of increased price on CO_2 emissions, while at the same time improve on air and water quality. The IEA (2017) also point to the fact that it would require both investments and policy to shift to a low-carbon energy path.

3.3.3 Products and Services

As consumer are getting more enlightened about consequences of carbon footprint and climate change, they also shift their preferences for product and services that's are more environmentally friendly. Firms that adapt to consumer's preferences through products and services they deliver, create opportunities to develop a greater position in the market.

3.3.4 Markets

Organizations that seeks opportunities in new markets can get a better position in the market and make themselves more resilience in the transition to a lower-carbon economy. The opportunity to change market exists through the whole supply chain, if it is not possible to change to a more environmentally friendly product/service, or the organization's product/service is already environmentally friendly, they can still exploit opportunities that reduce carbon footprint through other parts in their supply chain. (e.g., transport networks, green electricity or low-carbon production). Since governments, investors and banks are supportive to such adaption, there will exist opportunities to collaborating with them.

3.3.5 Resilience

The ability to respond and manage climate-related risks makes an organization more resilient to climate change. This resilience provides opportunities as it is attractive from investors and other stakeholders perspective, hence a stronger competitive advantage.

Wong and Schuchard (2012) argue that proactive responses to climate change are needed primarily to respond to three drivers: (1) potential shortages of raw materials; (2) disturbances in manufacturing facilities and distribution systems; and (3) impacts on consumers' purchasing preferences and needs. By being prepared for these changes, and not being too slow to adapt to these changes increases the resilience. Also, to have a planned course of action if these events were to happen. That is a part of what we are trying to establish in this paper; how to act on the anticipated consequences of potential outcomes of climate change. By doing this the business could increase both their risk awareness and the adaptive capacity, making it easier to see what needs to be done.

3.4 Recommended Disclosure

The guidance made from the Task Force is structured around four areas, these areas are core elements on how organization operate. This type of structure makes it applicable for all organization regardless of sector and geographical location. The way the Task Force simplifies the concept of climate-related risks and opportunities, and the structure they use in their guidance, helps the users to improve their information and understanding of financial consequences of climate risks (Norwegian climate foundation, 2017). The recommendations for disclosure works in a way that help investors to choose between winners and losers taking climate-related issues into account. We are going to give a brief explanation of each area, represented by TCFD (2017), accompanied by examples:

3.4.1 Governance

This area gives investors, banks and insurances the ability to see if climate-related risks and opportunities are given appropriate attention from the board and the management.

When considering the board's oversight, the Task Force highlight that organization should examine the information process of climate-related risks/opportunities, as well as the frequency of shared information to the board. How the board consider climate-related issues in their operations throughout the business. As well as, how the board monitors and controls the progress towards goals and targets related to climate-related issues. Under the governance area the Task Force also place emphasis on management's role linked to climate-related issue, with respect to assessment and management. This area focusses on climate-related responsibilities concerned with the managers, how they manage them and how they report to the board. In this section, it is important that organization report the organization structure linked to climate-related issues, as well as information process to the managers and how management monitor these issues.

One of the challenges with governance and climate-related risks is that they are prone to path dependence. Path dependence is the phenomenon that leads persons to repeat the actions of their predecessors. International collaboration and trust will be important in order to overcome the challenges of climate change. This is especially true when it comes to sharing of information and overcoming the issue of actors focusing on increasing their own personal gain from their positions and power (Leck & Simon, 2012; Aggarwal & Dow, 2011; Cavallaro et al., 2018). Governance path dependency has shown to influence environmental impact, and also less investment in projects that mitigate environmental risk. Further it might seem that companies with higher institutional ownership result in lower environmental policy adoption (Aggarwal & Dow, 2011)

3.4.2 Strategy

Climate-related issues can affect organization's structure, strategy and overall business in the short run and the long run. Stakeholders and investors are interested to know how these issues affect them, due to expectations of future performance.

The "strategy" area is divided into three different recommended disclosures in the Task Force's report (2017, p. 20-21); The first one addresses how climate-related risks and opportunities the organization has identified in the short, medium and long term. The second one concerns the impact of those risks and opportunities on strategy, business and financial planning. The last one, consider the importance of reporting the organizations resilience when taking into consideration different climate-related scenarios, such as the 2-degree target scenario.

It has also been shown that investors under-invest in long run projects when the company has a short-term strategy focus. This might lead to a problem for businesses that might be heavily influenced by climate change. Having a long-term strategy that encompasses climatic changes might very well be firm value maximizing. Therefore, climate risk strategies should be a part of a firms long- and short-term strategies, and also present in the companies' governance (Aggarwal & Dow, 2011).

3.4.3 Risk Management

To able investors and other stakeholders to understand organization's overall risk profile and risk management activities, organizations have to describe how they identify, assess and manage climate-related issues.

When organizations are identifying and assessing climate-related risks, they are recommended to determine the relative significance those risks compared to other risks. The Task Force also recommend that they identify potential size of the risks, as well as identify risk terminology and risks classification used. Organizations should also report their decisions on whether to mitigate, transfer, accept or control climate-related risks, and how their process are for managing those risks. The last recommended disclosure in this area is that organization describe how their processes for identifying, assessing and managing are integrated into their risk management.

One of the most relevant cases around risk management and climate, was the “Dieselgate” case. VW masked the real emissions of their cars with programming. This decision would have been made while being aware and accepting the climatic risk of this decision (Zachariadis, 2016). Due to the economic potential reward this choice is consistent with what we saw previously in the risk section of the paper; individuals can tolerate high levels of risk if the reward is high enough.

3.4.4 Metrics and Targets

Organizations that informs their metrics and target enable investors and other stakeholders to consider the organization’s risk-adjusted returns, exposure to climate-related issues, as well as their adaptability to manage those issues and financial obligations. In other words, this area is mean to create understanding on how the organization measure and monitor climate-related risks and opportunities.

Historically CEO compensation has been given by their achievements (e.g. profitability, market share, output, sales). To reach the goals, and satisfy the stakeholders, it is likely that the environment has been given less priority. As in the case of the U.S. power sector (Cavallaro et al., 2018), CEO compensation was calculated by the amounts sold even though much of the electricity was produced through the use of fossil fuel. Even though this is a calculation that makes sense for a short-term strategy in a profit maximizing business, it does not take the external/ societal cost of pollution into their calculations. As a consequence, the real cost to society is much higher.

4. Aquaculture

4.1 From Aqua-Capture to Aquaculture

After the second World War, Norwegian oceans and fisheries were mostly unregulated. This lead to overfishing, and especially fish like the herring was reduced almost to extinction up until the 70's. Due to concerns around the state of the fish stocks, they started to regulate the fisheries. This resulted in fewer and bigger fishing boats, and the fisheries sector was industrialized (Schwach, 2000). The fish should be rescued from the short term economic gains of the individual fisherman and become a public security for the future. Or in more economic terms, preventing the tragedy of the commons through regulations.

It is widely accepted that it was the consequence of the decreased amount of wild fish in the ocean and that the available shoreline of Norway were some of the reasons why aquaculture became a substantial industry in Norway. As a consequence of the rapid expansion of the aquaculture sector, banks and financial institutions became more willing to invest in the sector. This lead to an even more rapid expansion, and high debt ratios. Due to high debt ratios, many producers lacked private equity, which lead to insufficient capital when the prices dropped, or sickness occurred in the pens.

One of the first decisions was which species that were suited for aquaculture. Scientists agreed that the salmon and artic trout was the most suitable due to their survival in both fresh- and salt water (Schwach, 2000). In the beginning, selective breeding was the main method of altering the fish to increase survival rates and efficiency. The first step was to gather eggs from different wild salmon. During 1971-1974, samples was taken from 40 Norwegian rivers were taken and used in experiments. In the spring of 1970 the successful commercial smolting facility produced 20,000 smolts offshore Hitra island. During the 1970s a lot of the research around salmon farming was financed from the sale of eggs. Through the years there have been several improvements. For the years up until 2012, the time to produce salmon has been halved, while the feed consumption dropped from 3kg per kilo growth to 1.15kg per kilo growth (Gjedrem, 2012; Schwach, 2000; Hovland et al., 2010).

As a consequence of the technological improvements, and resource efficiency gains, the real production cost per kg of salmon has decreased by about 75 % in between the mid-1980s and

2004. This resulted in lower prices, and increased demand. In the same period the average size of licenses for aquaculture production increased from 47 tons to 652 tons. This enabled the producers to meet the increasing demand in the period (Asche et al., 2009). Even though the sector has seen a substantial decrease in the production costs, the cost-shares has changed considerably as seen in figure 4. Even though the price of feed has decreased, it became a much larger share of the total cost.

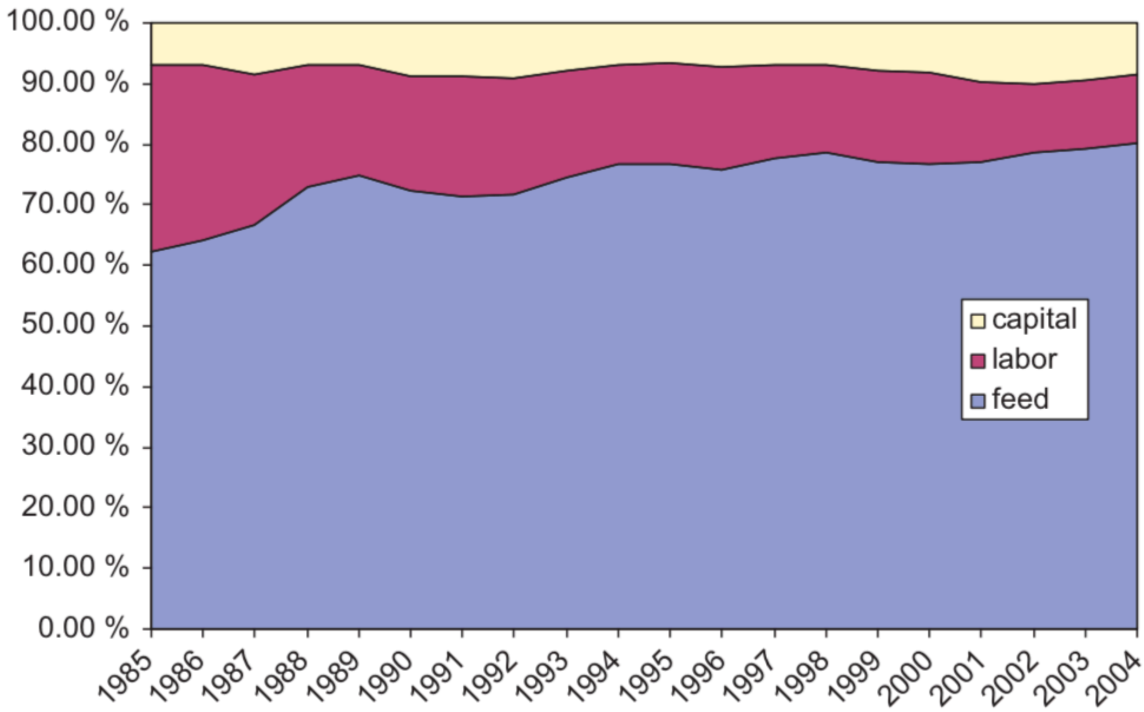

Figure 4: Cost shares in Norwegian salmon farming (Asche et al., 2009)

4.2 Aquaculture in Present Norway

Aquaculture has an important role in the Norwegian economy. 95 % of all seafood produced in Norway is exported, and it is the second largest source of income after the petroleum industry. Due to reductions in the oil price in recent years, it has become even more important for Norway as a net exporter. In figure 5, we can see the development of aquaculture sales from 2007 until 2017. From this we can see that the value has approximately doubled since 2010, while volume has increased around 30 in the same period. This means that the producers are dependent on the price of salmon, which means that the profitability of the sector will depend on future price development.

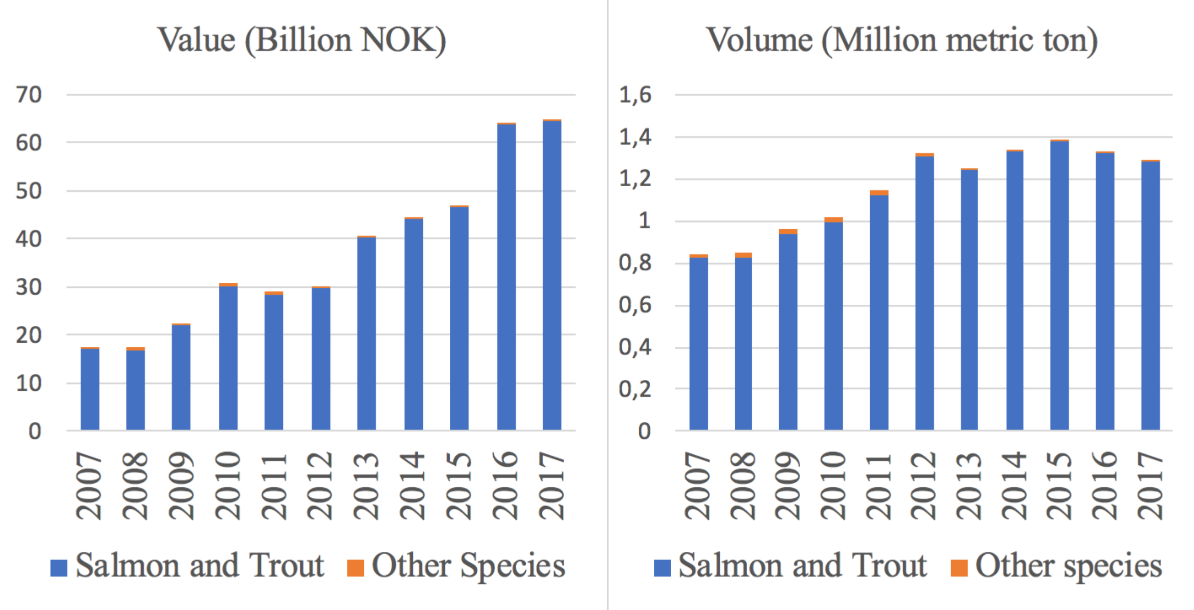

Figure 5: Aquaculture growth in Norway (Norwegian Seafood Council, 2018)

Norwegian Atlantic salmon and rainbow trout are both used in high-end restaurants and for everyday cooking. Due to global demand, the prices have been kept high and there has been demand surplus. How demand is going to develop in in the future could potentially be influenced directly and indirectly by climate risk. For many years the salmon and trout were only sold at spot-prices. This resulted in high volatility in prices, which lead to uncertainty and differences in revenue for the producers. Consequently, the banks stopped granting credit, and the companies struggled. In recent years the amount of futures has increased, reducing the volatility of the prices of salmon. However, the price of salmon is still one of the most volatile in the market, challenging the profitability within the sector (Jordal, 2014).

In Norway, permits are needed in order to be in the aquaculture business. To receive permits, the companies have to go through two steps. The first is a formal application to the Norwegian Directorate of Fisheries, in order to be allowed to qualify for the bidding process. The next step is an auction through the county municipality, where they assign the permits to the location. According to the Norwegian Directorate of Fisheries (2018) there are as of 05.02.2018, 18122 aquaculture permits in Norway. They are distributed between many actors, such as research facilities, universities and private organizations, although the vast majority is for seafood producers for commercial sale. The biggest producers of seafood in Norway are; Marine Harvest, Salmar, and Lerøy. Combined these three accounts for nearly one third of all the permits. About 3500 of these are registered as commercial food fish permits (Norwegian Directorate of Fisheries, 2018).

In 2013 the Norwegian Government opened for so called green concessions. These are divided between three groups; Group A, B and C. Group A was divided between Troms and Finnmark, while group B was divided through a closed auction across the country. In group C up to 10 concessions could be divided throughout the country. In groups A, and B, the applicants had to use methods which would either reduce the chance of cultured fish escaping or ensure that the level of matured female fish lice were less than 0,25 per fish in the pen. Further they were not allowed to use more than 3 medical treatments per production cycle. In group C the requirements were stricter. They would either have to significantly reduce the chance of cultured fish escaping or ensure that the level of matured female lice was less than 0,1 per fish in the pen. And the medical treatment requirements were the same as in group A, and B (Norwegian Directorate of Fisheries, 2017).

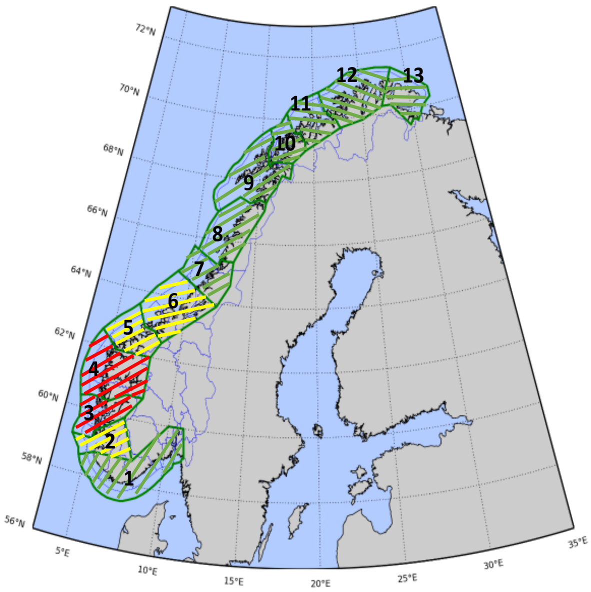

Figure 6: Traffic light (Norwegian Government, 2017)

In addition to the green concessions, the government also introduced a “traffic light”-system. The idea is that production-areas are given red, yellow, or green “lights”, depending on the governments assessment of sustainable growth. Red light means that the production needs to be reduced, yellow means that the production should be stable, and green means that production can grow. Into the assessment are factors like salmon lice and economic conditions (Norwegian Government, 2017). Figure 6 illustrates the governments “traffic light” system, and shows the areas were growth is sustainable. Most of these areas are located in the northern part of the country. This effort can be regarded as one of the first steps towards regulating climate risk in aquaculture, however at this point it only considers local pollution, and not the broad concept of climate risk.

Due to the rapid growth of aquaculture production, the non-profit Aquaculture Stewardship Council (ASC) was founded in 2009 by the World Wildlife Fund (WWF) and The Sustainable Trade Initiative (IDH) (ASC, W.Y). Their aim is to minimize Aquacultures impact on the both the social and environmental environment through (ASC, W.Y):

1. Biodiversity: Minimize impacts on local ecosystems
2. Feed: Minimize use of wild fish in feed and ensure traceability of feed ingredients
3. Pollution: Monitoring of water quality
4. Disease: Decreasing the use of chemicals, no prophylactic use of medicine
5. Social: No child- or forced labor

To get ASC certification, all these requirements must be me met. In Norway most of the biggest suppliers are either certified or committed to become certified in coming years due to their membership in the Global Salmon Initiative (GSI). Global Salmon Initiative was founded in 2012 to provide sustainable source of protein to feed a growing population as a collaboration between salmon farmers to improve the quality of their products and processes (Global Salmon Initiative, 2018).

4.3 Aquaculture Value Chain

As presented in the section about aquaculture development, we can see that the seafood market has changed rapidly during the last decades. The traditional fish market has disappeared, and retail chains have taken over. Innovation and technology are the main sources for this development. Fish farming allowed the companies to take control of the production process, from production of eggs to sale, which again led to reduced production cost. This development shows that aquaculture has moved from a labor-intensive to a capital-intensive production, and machines have taken over links in the supply chains such as sorting, slicing and gutting (Kvaløy & Tveterås, 2008). Increased profitability and competition in the industry has resulted in higher supply and lower prices for the consumers, see figure 7 (Asche, 2008). The development from fish capture to fish farming resulted in increased productivity, lower production costs, as well as larger companies (Asche et al., 2013).

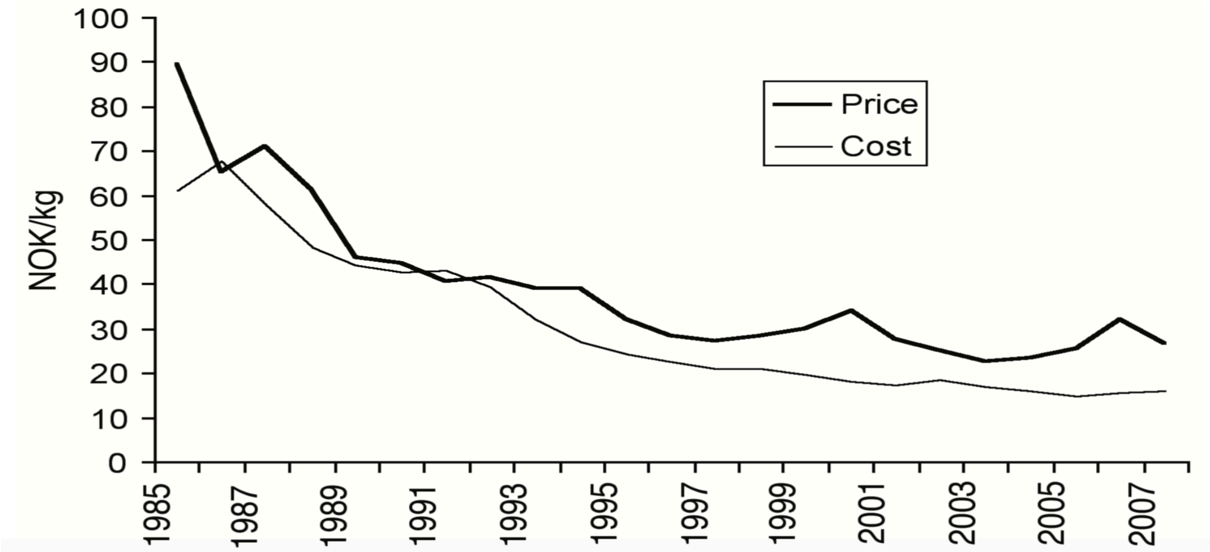

Figure 7: Real Norwegian Production Cost and Export Price for Salmon, NOK/kg, 1985-2007 (Asche,2008)

Similar to the agriculture sector, control of the product process has allowed more focus on specific processes, which again has led to increased specialization in production processes (e.g. feed, breeding, disease control). However, the increased size of the industry has also led to specialized suppliers (Asche, 2008). Large companies often have employees that are specialized in different fields, while small companies are more dependent on these specialized suppliers. The growth in the industry has resulted in an increase in size of the companies, especially for salmon farmers, however there are still some smaller companies (Asche et al., 2013).

Vertical integration is when companies include several steps of the value chain into their own business. One example could be that a manufacturer also is the producer of their own inputs. By being able to increase profit through selling the surplus of that input factor they are increasing their profit, and at the same time getting more cost-effective through control over more processes in the value chain. Horizontal integration is when companies include new business activities at the same level in the value chain in the same or different sector. Benefits here could be benefits of scale and/ or scope and increased market power (e.g. reductions in the number of actors in the aquaculture sector in Norway). What these have in common is that they «smooth» the value chain, by obtaining more control of the processes surrounding the production, thereby reduce risk. To reduce the likelihood of illnesses and parasites transferring between locations, companies often have production in several parts of the world, which is an example of horizontal integration (Giskeødegård, 2014). Potential side effects of integration are increased barriers to entry and decreased research & development due to fewer companies and less competition.

Since salmon farming is the fastest growing sector (Kvaløy & Tveterås, 2008), with the most industrialized value chain in aquaculture it would be natural for us to focus on salmon farming. In salmon aquaculture, we see the tendency of companies becoming larger and value chains being expanded through vertical integration. Some of the largest companies within salmon farming has also integrated feed production, for example Marine Harvest. As value chains expand, contracts become more important to handle risks related to quantity and price. Suppliers play a significant role in relation to the company's resilience, which highlights the importance of a good relationship with several suppliers throughout the value chain. If a salmon farmer is dependent on a single feed supplier, and that supplier experience a halt in production, the farmer becomes unable to get input factors, causing the production process to slow down.

Control over the production process has resulted in specialization, technological advances in specific processes, and enabled the companies to reach large-scale production. However, there is a strong relationship between control over the production process and intensity (Asche, 2008). Unlike salmon aquaculture, mussel farming is one example of low-intensity production. In mussel farming, the farmer usually provides a rope for the mussels to fasten onto, and since mussels lives of phytoplankton and particles in the ocean there is no need for feeding. This means that this production requires significantly less interaction. High-intensity farmers with control over the production processes can continuously improve their production process. Degree of interaction in a production process depends on which species that are produced, and for salmon farming it would be a lot easier to reduce cost of bringing the fish to the market because of the production control.

Returns from research, development and learning gradually starts to diminish, which again slows down the marginal productivity. Asche and Oglend (2016), argues that the output price of salmon has become more input driven than productivity driven after this slowdown in productivity growth. For salmon farming, feed is the biggest contributor to operational cost indicating that variation in feed raw material explains variation in production cost, which again means that the price of feed raw material determines the sale price, showed in Figure 7. Since climate change can cause changes in input prices it is possible that climate-related risks might affect the price of salmon, thereby affecting the industries product market and investments in the longer run.

Figure 8 shows the production process of salmon, which is the main link in the value chain of salmon. Understanding of this process helps to understand and analyze the mechanisms of end-product price. Aquaculture is a production process, where each step is controlled. First step is to either buy or produce the eggs from stem fish and let them grow in monitored tubs of fresh water. The next step is hatching the eggs and letting the smolt grow to the appropriate size before being transferred to the sea. They mature in the sea, before being returned to shore for slaughter, distribution and sales.

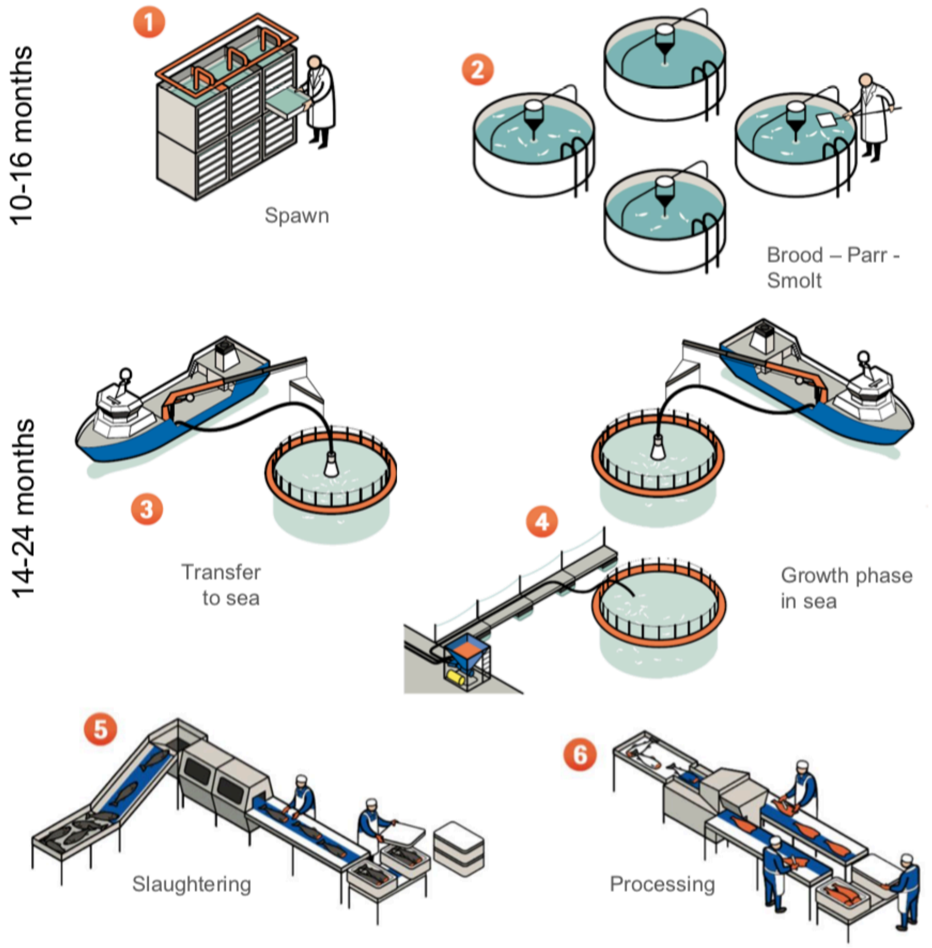

Figure 8: Production Process for Salmon (Marine Harvest, 2017, p.40)

From figure 8, we can see the development of salmon from spawn to processing. In total, this process takes around 24-40 weeks depending on location, time of year and processing methods (Marine Harvest, 2017). As seen above the aquaculture process is quite simple.

However, there are many actors involved in such a process. In each step, there is a lot of infrastructure, buildings and transport needed.

When looking at salmon farming, there are two important decisions; when to transfer the smolts to seawater and when to harvest the fish. The question about smolts transfer raises due to biological reasons, as they can only be transferred during a certain period of the year; March-October in Norway. The growth of the salmon would therefore depend on when the fish are transferred to sea. Since all farmers face the same dependency on aquatic environment and biological conditions, as well as have the same objective (i.e. profit maximization) for the production process, we therefore assume that transferring- and harvesting time would be the same for all farmers throughout this study.

Landazuri-Tveterås et al. (2018) also found that price transmission lessens with the degree of value added. Thus, a processed or semi-processed salmon product will be less dependent on the export price of salmon. Possible explanations of this would be that as the number of processes and other raw materials increases, the export salmon price will become a lower percentage of the total product price. The authors continue to say that due to the generally low number of processes involved in the salmon value chain, most of the commercial products have clear price transmission from the export price of salmon. Price transmission will therefore vary across markets, depending on the consumer preferences in the different market. Fresh salmon must be delivered more quickly than frozen due to the perishability, and depending on the distance, this will also have implications for the chosen mode of transportation.

5. Climate Risks in Aquaculture

Farmed salmon is one of the most resource efficient sources of protein for human consumption. In table 1 we can see the difference between Atlantic salmon and other food production. From a raw materials perspective, we can see that salmon has a higher edible yield than any of the others, an at the same time it requires far less feed in order to grow 1 kg compared to other sources (Feed Conversion Ratio). This results in 61 kg of edible meat per 100 kg of feed, which is substantially higher than any of the other protein sources. This is up to 6 times more effective than for cattle, while at the same time the carbon footprint is about a tenth, and water consumption is around an eight.

	Atlantic Salmon	**Chicken**	**Pork**	**Cattle**
Edible Yield	68 %	46 %	52 %	41 %
Feed Conversion Ratio	1.1	2.2	3	4-10
Edible meat per 100 kg feed	61 kg	21 kg	17 kg	4-10 kg
Carbon Footprint (kg CO2/ kg edible meat)	2.9 kg	2.7 kg	5.9 kg	30 kg
Water Consumption (liter/kg edible meat)	2,000 liters	4,300 liters	6,000 liters	15,400 liters

Table 1: Atlantic Salmon Comparison (Marine Harvest, 2017)

Due to the world being 70 % water, a substantial amount of our food should come from the oceans, however only about 5 % is produced there. Aquaculture seems to be polluting less than conventional agriculture, and at the same time there is a substantial growth potential within the sector. Nevertheless, aquaculture still face climate risks, that need to be identified to develop risk assessments and from this develop the appropriate risk response (Handisyde et al. 2006). To identify the climate risks, we will utilize the TCFD framework from figure 1. We will first study the physical risks and opportunities the sector faces before examining the transition risks.

5.1 Physical Risks and Opportunities

Physical risks are caused directly by climate change. This could be global warming, CO2 acidification of the oceans, sea level rise, and extreme weather (Ellis et al., 2017). As mentioned the physical risk can be divided into acute and chronic depending on the urgency of the risk. Acute physical risks refer to those that are event driven, while chronic risks are shifts in climate patterns in the long run.

Hurricanes, floods and cyclones are examples of acute risks. Due to the geographical location of Norway, we are less prone to hurricanes, tsunamis and cyclones. However, Norway experiences extreme weather events such as floods and storms every year. These have impacts on transportation infrastructure, and physical assets. Destruction of net pens, and harsh weather conditions for boats could also significantly impact the sector.

Sea level rise due to global warming, is expected to be between 10-100cm during this century, due to thermal expansion and melting glaciers. For the aquaculture industry, this might cause challenges for smolting facilities near shore and the docks they use. Further this could be made worse due to more extreme weather, as a consequence of shifting currents and global warming. Scientists have argued that the global aquaculture industry will suffer due to global warming and more extreme weather conditions (Brander, 2007).

CO2 acidification due to the increasing amount of carbon dioxide in the oceans could become a concern. According to Ellis et al. *(2017)* about a quarter of our anthropogenic pollution has been absorbed by the oceans. They further point out that this will cause consequences for the aquatic species, which in turn will be a danger to the worlds food supply. Especially during the smolting and the first growth stages the salmon shows clear signs of reduced growth due to higher CO2 levels in the water. At later stages the salmon is more adaptable, however it could be a potential challenge (Ou et al. 2015).

Increasing water temperature could also be a challenge for the sector. Since fish are poikilothermic, which means they have the same temperature as their surroundings, they are dependent on water temperature. The temperature directly influences a fish's physiology, growth and activity. For many species of fish this will be a problem, and wild fish will move north due to temperature increases. The species used in Norwegian fish production is Atlantic salmon (salmo salar), which has an optimal temperature of 13-17 degrees Celsius (Ficke et al., 2007). This means that for the Norwegian aquaculture sector, a temperature increase due to global warming might not cause an immediate decline in the quality of the fish, and northern production might increase due to temperature increase and more open waters because of melting ice (Brander, 2007).

For the Norwegian aquaculture the physical risks will mainly have implications for the input market, and other links in the supply chain. Fish feed production due to migration of pelagic fish and disruptions in transportation due to extreme weather conditions are examples of this. These issues will be further discussed in the section "Implications of Climate Risk in Aquaculture".

5.2 Transition Risks and Opportunities

Transition risk arise from the transition to a low-carbon economy. Aquaculture is a relatively young production method, and changes in both the production methods and the sector in general are frequent. In this section we will identify potential policy and legal-, technology-, market-, and reputation risks faced by the sector.

5.2.1 Policy and Legal

The challenge of managing and regulating aquaculture is due to uncertainty and lack of knowledge about the relationship between production and its effects on aquatic environment and stakeholder's interests. The externalities of aquaculture highlight the importance of government regulations. Regulations and policies consist of licenses, permits and production limitations due to fish health and environmental impacts. When designing policies and measures, a government account for both producers and consumers, where the attempt is to maximize social welfare. This means including both negative and positive consequences of aquaculture operations, where negative impacts concern environmental emissions, diseases and lice while positive impacts concerns access to work, food and health securities and economic growth.

Salmon lice or Leopeophetheirus Salmonis has been deemed as the biggest current environmental challenge within aquaculture. Due to increased aquaculture production there are much higher concentrations of salmon, than what occurs naturally. This makes it much

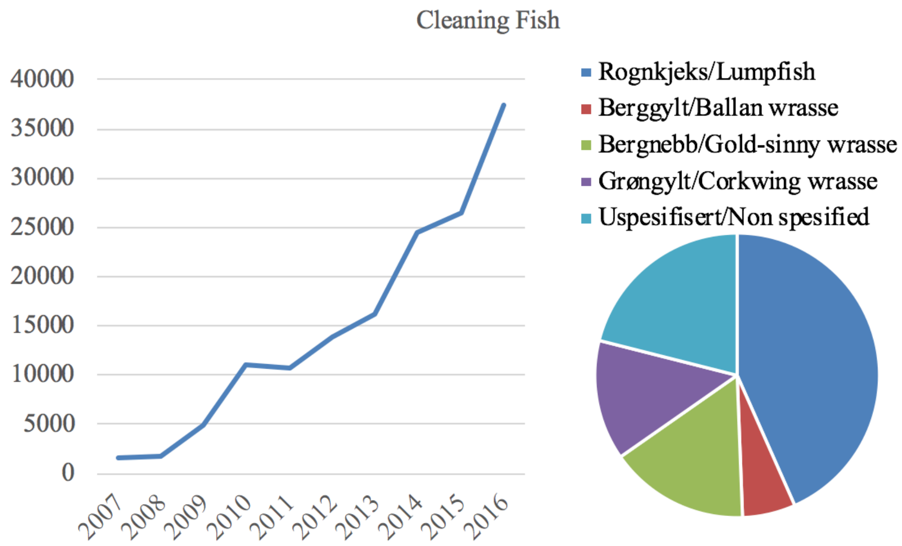

Figure 9: Usage of Cleaner Fish (Norwegian Directorate of Fisheries, 2017).

easier for the lice to transmit and procreate, resulting in vast amounts of eggs drifting in the water, and transferring to the wild population. The salmon lice feed of the skin and blood of the salmon, and through wounds other diseases fungi can thrive. In order to reduce the number of lice, the sector has used medical treatments in the water and feed. As mentioned, regulations to control the lice population already exists through the traffic light system and green concessions. Due to the lice becoming more resistant to medical treatments, mechanical treatments have been intensified, these include rinsing with temperate- or salt water. Other measures such as cleaner fish that eat the lice form the salmon are becoming more and more utilized (Lusedata, W.Y.). As one can see from figure 9 there has been a significant increase in the number of cleaner fish, most notably the Lumpfish. Stien *et.al* (2005) found a positive connection between salmon lice and ocean temperature. This means that global warming could make salmon lice an even more difficult challenge for the sector. Salmon lice becomes a transition risk due to regulations. These regulations aim to maintain an environmentally sustainable development and preserve economic growth.

Net pens are widely used because of their relatively simple design, they are easy to install, requires little maintenance, and use low cost materials. Low-cost materials and low-maintenance make the pens vulnerable to wear from storms and harsh weather conditions, which make the pens weak over time. This occasionally lead to breakages and escaped fish.

The Norwegian Directorate of Fisheries (2017) started a new project in 2015, called development licenses, which aims to solve some of these issues by providing locations for R&D of more durable and technologically advanced solutions. Marine Harvest (2017) is one of the companies that have taken advantage of this opportunity and have started to develop several new pen-designs both for sheltered and exposed locations at sea.

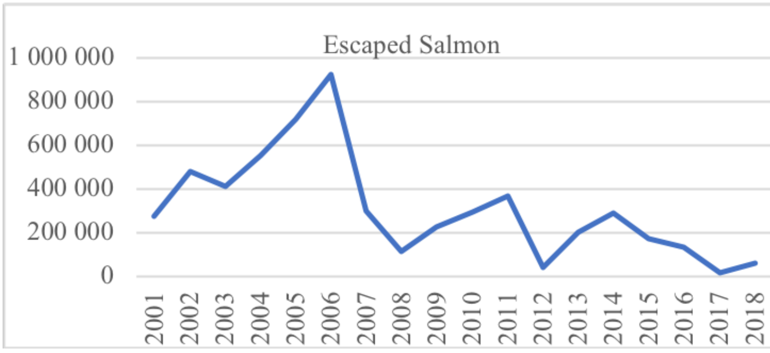

Figure 10: Escaped Salmon (Norwegian Directorate of Fisheries, 2018)

Fish that escape from the cages procreate with the local wild species and threatening the natural biological order. According to the Norwegian "Institute of Marine Research" (2016) escaped salmon and salmon lice are the two biggest environmental problems for the aquaculture sector. It is uncertain what the short- and long-term effects of escape is going to be for the biological diversity in the rivers and fjords. Both the fact that the escaped fish procreate with wild individuals and that they transfer salmon lice make this a challenging problem. From figure 10 we can see that the number of escaped salmon has decreased in recent years, because of focused work to reduce the likelihood of escape. Lice and escaped salmon can be seen as pollution from the aquaculture sector. Even though it does not release CO_2, it results in a social cost for society that is not directly payed for by the producers.

Waste from aquaculture production include both fish feed not being eaten by the salmon, along with fecal matter from the salmon. Normally most of this is eaten by other organisms living close to the fish pens, however, there are dissolved compounds that escape into the ocean. This includes nitrogen and phosphor. This could over time become a problem due to pollution of the oceans. Some of the dissolved compounds are being consumed by shellfish and microbes, however, this is also hard to calculate due to currents, and complicated biological factors. These are discussed in the rapport by Karlsson-Drangsholt & Nes (2017).

Fish feed production is considered to be the most vulnerable aspect of aquaculture in respect to climate change, because of the dependency of fishmeal and fish oil (Cochrane et al., 2009). Norwegian aquaculture exists primarily of Atlantic salmon and rainbow trout, both of which are carnivorous species that depends heavily on these raw ingredients. Approximately two thirds of fishmeal and fish oil comes from specialist production, and in developed countries much of these ingredients are imported from developing countries. In Norway, there is a surplus production of fishmeal, however fish oil is a deficit good which we need to import (Handisyde et al., 2006). Feed production might be a highly relevant climate risk for the Norwegian Aquaculture sector. Since the 1990´s there has been a united effort to reduce the dependency of marine resources to produce feed. This has led to some new challenges which will be presented in the section "5.2.3 Market".

A higher tax on emissions and/ or carbon cap-and-trade, are measures that are being considered in order to reduce emissions. For the aquaculture sector, the implications of such a regime would affect both feed production and modes of transportation. Ziegler et al (2013) found that the amount and type of feed was one of the main influences of the carbon footprint, combined with the mode of transportation. Whether the fish was fresh or frozen would only matter if it involved a change in transportation. Another study concentrated around fillets (functional units) from hatching to consumption in a life cycle analysis Ellingsen et al. (2009) .They found that the emissions of CO2 depend on whether the fish is produced using fossil fuels or natural gas, and therefore varied between 2,2 kg and 3,0 kg of CO2 equivalence. Both Ellingsen et al. (2009) and Ziegler et al. (2013) agree that the main contributor to the greenhouse gas emissions are feed production, and that the transport modes are less important per kilogram, due to the amounts of fish produced. On the other hand, the increase in use of airfreight might have increased the emissions from transport. In figure 11, we can see an example of a lifecycle analysis, where one can clearly see that the “Farming” process is responsible for the majority of greenhouse gas emissions. This process includes the production of feed.

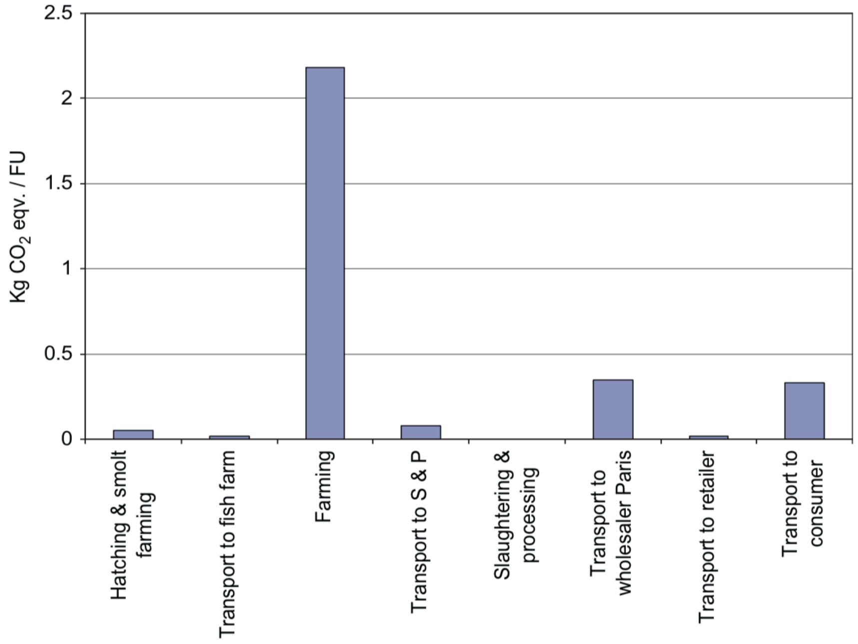

Figure 11: Greenhouse gas Emissions per Functional Unit of Atlantic Salmon (Ellingsen et.al., 2009)

5.2.2 Technology

Developing technological solutions that reduce the impact on the environment should be a priority; where the technological development considers both societal cost of aquaculture and maintain growth potential. The most transformative technology in the last decades have been digitalization. Camera surveillance, real time data analysis and automatization are just a few examples of how technology has increased resource efficiency and control of the production.

Transition towards lower emission solutions include transportation, both to and from the pens, transport of raw materials and products. Electrification of boats and other transport with reductions in the use of fossil fuel generators for electricity are some of the possibilities for improvement. What these options have in common is that they require substantial investments, since some of the cages and facilities are located in remote places without access to the electricity grid.

In an effort to reduce the numbers of escaped salmon and fish lice a new company called Hydro Salmon Company have been assigned 4 development licenses from the Norwegian Directorate of Fisheries in order to test their new cylinder-shaped steel tank. The idea is that fish lice will not be able to enter the tank, and if they do their eggs will not stick to the smooth and hard surface. Another benefit with building in steel is that it will be less vulnerable to drift, collision or wear and tear, reducing the chances of escaped salmon (Directorate of Fisheries, 2018). Marine Harvest have also been assigned a development license for their "egg" design in collaboration with Hauge Aqua for an enclosed tank. They are starting testing of this design in 2018. This is a much more technically advanced prototype then that of Hydro Salmon Company, and aims to significantly reduce both fish lice, and spilled food resources (Marine Harvest, 2018).

Genetic enhancement has helped the Atlantic salmon become more resource efficient; through selective breeding the production time has been halved, and the freshwater survival rate has improved. New technologies, and reductions in cost has opened for the opportunity to use genome sequencing technologies for growth increases, disease resistance and survival, and tolerance to general stress. Genetic enhancement might also in time increase knowledge of interactions between the species used in aquaculture and externalities such as feed, global warming, ocean acidification (Yue & Wang, 2017). This will help the efficiency and sustainability of the aquaculture sector. Marine Harvest is one of the companies that are starting to take advantage of this technology through genomic mapping, allowing them to select the best possible broodfish (Marine Harvest, 2018).

5.2.3 Market

As we mentioned in the physical risk section, fish feed may be the biggest problem with regard to climate risk. When it comes to the raw materials, there has been a steady decrease of the marine ingredients in the feed, which has reduced the dependency of fish oil and fish meal. The substitution towards vegetable protein happened due to a decrease in supply of the marine ingredients, which increased the price (Handisyde et al, 2006). However, since aquaculture is expected to grow at an annual rate of approximately 4 % through 2022, which means that even though there has been a decrease in the amount of marine ingredients, the demand might increase. The decrease in marine resources has led to a problem of finding suitable proteins (Gachango et al., 2017; Torrissen et al., 2011).

In the introduction of this section we represented a table showing the efficiency of salmon feed consumption compared with e.g. cows and poultry. This table is based on the feed conversion ratio, which describes how much input (feed) is needed to produce 1 kg of fish. Another interesting measurement is to see how much wild fish that is needed to produce farmed fish, the ratio used is fish in – fish out ratio, shortened to FIFO (Tvete, 2016). Both these measurement shows the dependency on feed and feed ingredients in the production of salmon, and useful measurements to get an overlook of the input mix, which again could be helpful in the attempt to change an inefficient product mix.

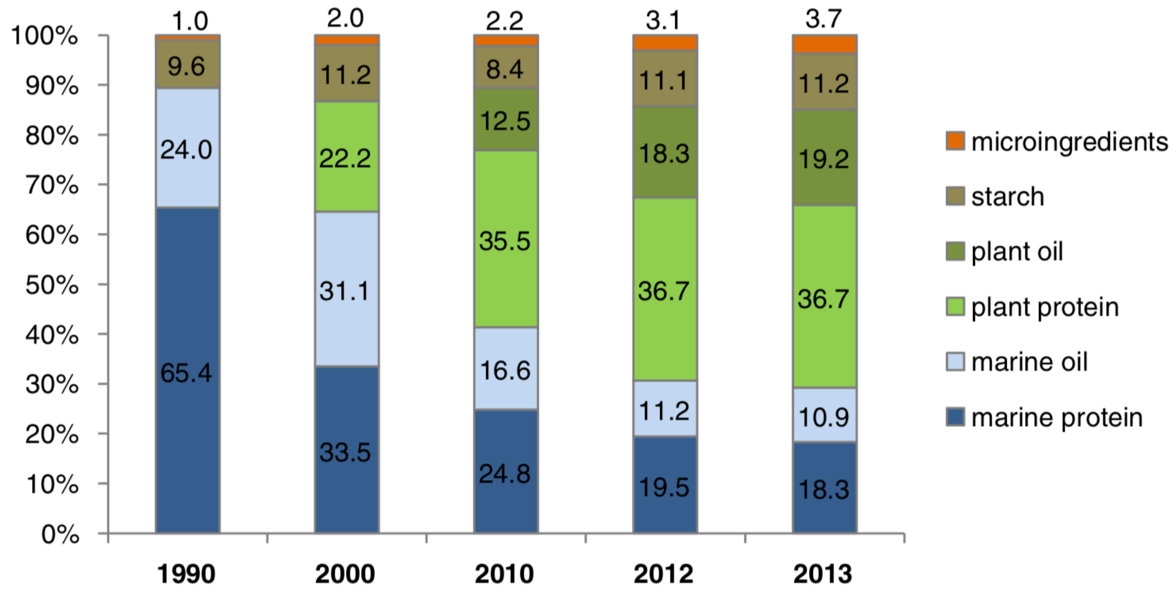

Figure 12: Feed ingredients 1990-2013 (Ytrestøyl et al., 2015)

In order to reduce the dependency of fish oils and meal; vegetable oils, like rapeseed oil and soy are being used as a substitute. In 1990 about 90 % of the ingredients in fish feed was from marine resources, while in 2013 this number had dropped to about 30 % (Ytrestøyl et al., 2015). As a result of this, 0,7 kg of marine resources was needed to produce 1 kg of fish in 2013, while 4,4 kg was needed in 1990. This tendency can be seen in figure 12, which also shows that the dependency of vegetable ingredients has increased. Some of these vegetable ingredients is from soy beans. Soy beans are one of the main contributors of rainforest deforestation, making aquaculture a contributor to the destruction of rainforests. This consequently makes feed producers and thereby the aquaculture sector vulnerable to the state of the rainforest, and policies and regulations surrounding it (Austin, 2010).

All vegetable proteins unlike some marine ingredients have to be imported to Norway. Since these vegetable ingredients are grown in southern countries, they are more fragile towards the physical climate risks mentioned in the physical risk chapter. Especially drought, sea level rise and extreme weather might reduce the availability of these resources. Resource scarcity and increased prices of marine resources was one of the main reasons why vegetable proteins were an appropriate substitute. Climate change, and increased physical risks might turn this trend, making vegetable proteins and oil more expensive, and thus reducing the benefit of this substitution. As one can see from figure 13 feed also accounts for around 50 % or total production costs, which highlights the sectors sensitivity to price changes in this part of the production.

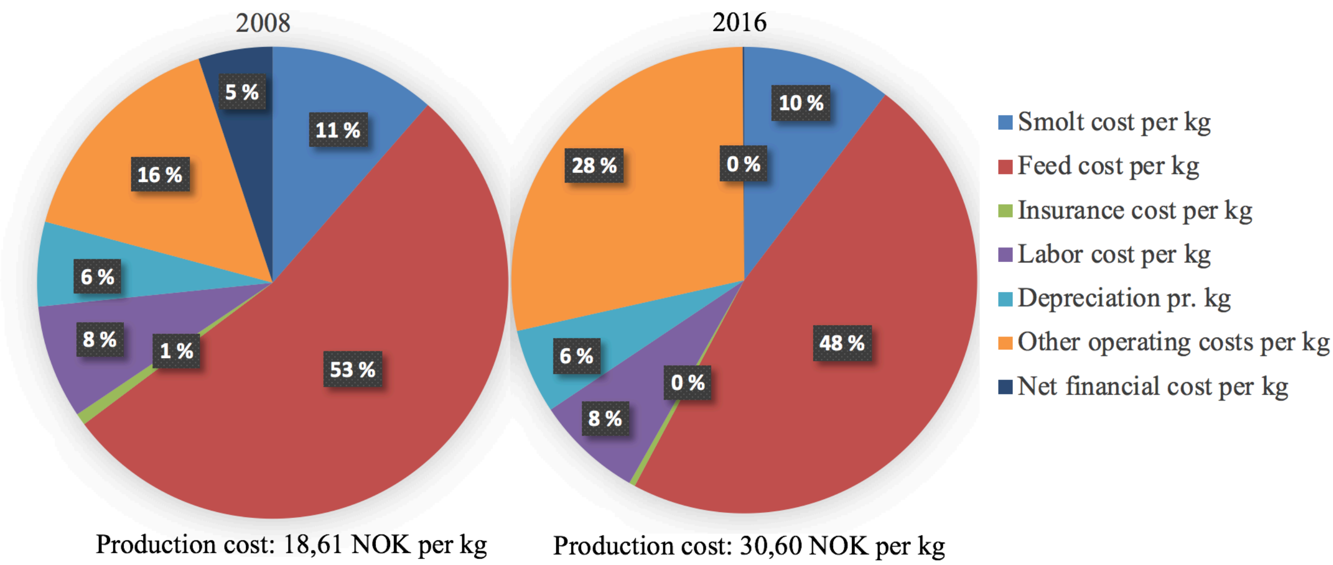

Figure 13: Production costs per kg foodfish (Statistics Norway, 2018)

5.3.4 Reputation

As with other sectors, the aquaculture sector also needs to take their reputation into consideration. Both vegetable and marine resources are harvested in rural areas, and scientists have argued that the species and plants used to produce these ingredients should rather be allocated to the local population (Gachango et al., 2017; Troell et al., 2014) As climate change might worsen their regions, feed producers in general might face bad publicity due to their utilization of the scares resources. This might reduce the demand for fish, thereby decrease the revenue from production.

Another potential issue is the consumer perception of the impacts on the local environment, both salmon lice and escaped salmon around the pens. In Norway both leisure fishing and tourism utilize the rivers and streams, due to the salmon lice, and escaped salmon, there has been a decrease in the quality of the wild population. This might alter the consumption preferences, and thereby reduce the demand.

An example of how reputation could damage the sector is what happened after the article "Global Assesment of Organic Contaminants in Farmed Salmon" was published. The article looked at environmental toxins in farmed salmon and found that the concentrations of PCB and Dioxin resulted in increased risk of cancer. These results received considerable media coverage, and as a result demand dropped significantly. In this case the sector rapidly fought of the accusations, and due to efforts in marketing there was no long-term reductions in demand (Gruben, 2007).

6. Implications of Climate Risks on Aquaculture

From a risk management perspective, risk identification is essential to be able to understand why one should undertake risk management activities. After identifying and evaluating risks it is possible to undertake risk management activities that includes responding the potential impacts, whether this is to terminate, treat, transfer or tolerate them. After identifying climate-related risks and opportunities that the aquaculture sector faces, we are now going to examine possible impacts that influences the sector.

Attention towards climate changes and the understanding of what it implies seems to be increasing, but there still exist few reporting requirements. Since stakeholders have an increasing demand for access to climate-related risk information, firms and markets should incorporate these expectations into their risk management activities. As climate-related risks could cause concerns at different levels in the industry (i.e. finances, reputation, infrastructure and marketplace) we are going to study implications of climate-related risks and opportunities on different segments of the sectors. We simplify our study by looking at submarkets that seems to be most vulnerable to climate change, and thereby getting a general overview of the sector as whole. The different segments we are going to focus on is;

1. Feed Market
2. Labor Market
3. Product Market
4. External Conditions
5. Investments

Each of these segments capture different opportunities and challenges. Shown in figure 11, farming is the most polluting link in the value chain and based on this finding we abridge our analysis by looking at input-factors in this part of the value chain. "Feed Market" captures the most important input for the producers and is necessary for the production. As we saw earlier the feed market is also the biggest contributor to greenhouse gas emissions, making it an important climate risk. In "Labor Market" we analyze how the aquaculture sector is dependent on labor, and the consequences for the Norwegian society. "Product Market" is a study of the end product, and how it is affected by climate risks and opportunities. "External conditions" examines the social, economic and ecological factors surrounding the industry, and are not directly controlled by the producers. "Investments" analyze the financial impacts of climate-related factors, and the future expectations. Through this approach, we will see how the segments are individually affected by the climate-related factors both in the short- and long run, and how they collectively influence the sector as a whole.

The structure of our analysis is based on the TCFD recommendations, where we have frequently used figure 1 to see how different identified risks and opportunities financially affects each submarket. The layout for our analysis concerns the dynamics of a value chain, by first looking at input factors that is necessary in production - and transformation processes and how climate related-risks could conflict with the markets of input factors. Next, we are investigating how these implications affect the end-product, the output of the value chain. From microeconomic perspective, we are looking at raw material and labor, feed market and labor market respectively, and thereby how climate- related risks and opportunities in the markets and the market's microeconomics dynamics affect the end-product and investments.

6.1 Feed Market

Due to the product markets dependence on the feed market, this is where we will begin our analysis. As discussed earlier, the aquaculture sector is becoming more input driven, and since feed is a major input it will have implications for the sector as a whole. From microeconomic theory we know that producers practice cost minimization, finding the combination of capital and labor that minimize the firm's total costs. In aquaculture, the level of raw material (e.g. feed) if fixed based on the desired level of output. Since substitution to labor is not possible for this part of capital, this cost is fixed in the short run.

6.1.1 Climate-related Opportunities

The Aquaculture Stewardship Council combined with the effort of The Global Salmon Initiative represents one of the opportunities for the Aquaculture sector. Competing firms cooperating to find sustainable solutions are a huge step in the right direction. Especially for the feed market and production process since this has shown to be the most risk prone part of aquaculture production. Such cooperation could increase the R&D for feed substitutes, reducing the carbon footprint from this part of the sector.

The feed market is the part of the aquaculture that has changed the most. Significantly increased resource efficiency and diversification has resulted in lower consumption of feed per kilogram fish, and lower feed expenditures for long periods. Automated feeding, and other inventions have also resulted in reduced waste of the feed, resulting in cost-savings. There is a possibility for further increases in resource efficiency, however one might expect that any further increases may be difficult and expensive to achieve given the efficiency of todays feed.

As the supply of raw ingredients are threatened, searching for substitute raw materials is now a priority for the sector. Finding suitable substitutes, is difficult due to the requirements of protein. Using by-products from production of other animals are being researched, and also the use of new marine ingredients, such as sea weed. Both of these technologies are still in the development phase, and a lot of research and investment is needed before they will be a viable option. Over time these solutions might improve the sustainability of feed, and possibly reduce costs in the long-run.

6.1.2 Climate-related Physical Risks

Due to the dependency of a steady supply of marine and vegetable resources, droughts, hurricanes, and other natural disasters might cause immediate supply shortages for the raw ingredients in the feed. In turn these shortages would most likely cause a spike in the price of feed, or even a shortage in the supply. Decreased production capacity due to a lack of raw materials and increased capital cost due to damage to facilities are possible consequences. A decrease in production capacity would lead to a loss of revenue due to lower output and sales, while increased capital costs would increase the costs, and thereby reduce the profits. These consequences will most likely be short term due to the passing of acute risks, however destruction of facilities could require investments that would result in higher depreciation and amortization in the longer run.

As previously discussed climate change can also be chronic. Due to global warming, and other climatic changes, weather conditions, land and sea areas could be permanently changed. Many of the raw ingredients are grown and caught in places vulnerable to chronic climate change. Especially pelagic species used for fish oil and fish meal are being overfished, and chronic risks may make the situation worse. In figure 14 one can see a representation of this problem. E_{MSY} represents the maximum sustainable yield and represents the maximum amount one can fish without reducing the population of fish, when growth is accounted for. To the left of this point the stock will increase, while it will decrease on the right side. E_{MEY} represent the maximum economic yield, or the effort where the difference between the revenue and cost is greatest. The problem is that when fisheries are unregulated, the fishermen do not consider the total cost and the total benefit for the society, they only care about whether they individually make a profit. This phenomenon is known as the "tragedy of the commons", and in this case it leads to overfishing, and diminishing stocks, as seen where the total revenue is equal to the total cost.

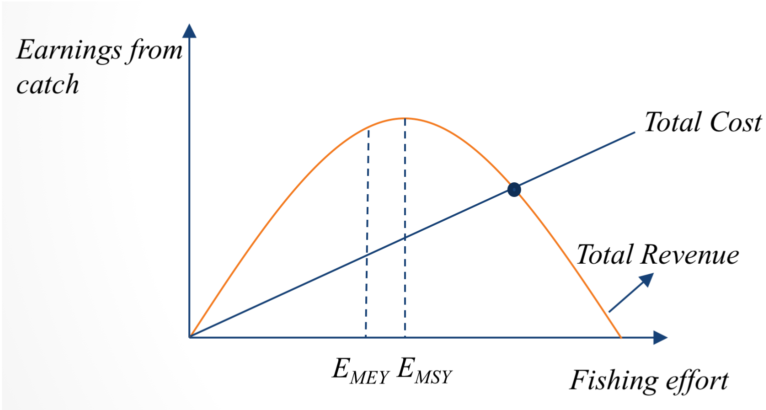

Figure 14: Harvest of Pelagic Fish

Supply-chain disruptions from the lack of fish meal, fish oil and vegetable resources combined with the early retirement of facilities in these areas would result in lower revenue, reduction in supply and write-offs. In contrast to the acute risks, this will most likely be a slower process. On one hand this gives the sector the ability to come up with risk managements techniques and examine possible solutions such as substitutes to the ingredients, thus reducing their "FIFO"- ratio, or increasing the number of available suppliers to increase resilience. On the other hand, the changes could be vast and thereby hard to fully anticipate, in both cases monitoring and assessing the possibilities for handling the risks are important.

6.1.3 Climate-related Transition Risks

Physical climate risk is as we have seen not the only potential threat to the feed market. Aquaculture is predicted to have a continued growth, which means increased demand for feed, which is why it is important to also consider the transition risks. Due to feed production being the most polluting part of the production, this is also the part of the supply that is most vulnerable in terms of tradable quotas or increased tax on CO2 emissions. If these measures are intensified, as a means to reach the Paris agreement, finding substitutes, increasing efficiency or reducing the carbon footprint of the production are viable solutions. This might however seem to be difficult due to the requirements of the feed.

In recent years there has been increased pressure to preserve the rainforests of the world. Substantial areas that used to be rainforest is now being used for growing soy-beans and other vegetables that can be sold and exported. In order to preserve the rainforest and its CO2 scrubbing abilities, reducing or stopping deforestation has been discussed. This would limit the potential availability of vegetable resources for feed production. In figure 15 one can see what happens to the price for the consumer (fish farmer) when there is scarcity in raw materials. Due to increasing nature of marginal cost curves (*MC*), the price for the consumer increases more than the quantity (p^0 to p^1 vs q^0 to q^1). Unless the producers are able to find more unconstrained inputs, one can see from the graph, that the price will continue to rise.

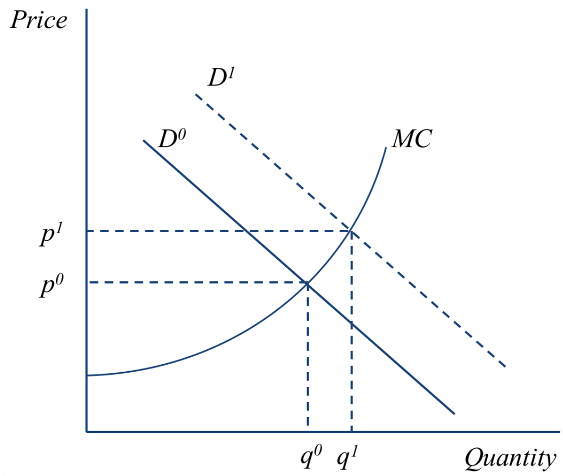

Figure 15: Demand and scarce resources

From a reputational perspective, both the vegetable and marine resources could be seen as a transition risk. Production of these raw materials are in general from rural areas, and research has shown that local farmers and fishermen could have utilized the areas for food production to increase their own consumption. A potential consequence could be decreased demand for farmed fish as consumers becomes more enlightened about the supply chain and the impact of the industry. In figure 16 one can see that this would create a leftward shift in the demand curve (from D^1 to D^2). This would in turn create higher prices for the feed consumers (producers of fish) from p^* to p^2, reducing quantity supplied from q^* to q^2. The effects, and the shape of the demand and the supply curves depend on the severity of the drop in demand, however it would reduce demand and lower the prices, resulting in decreased revenue for the producers.

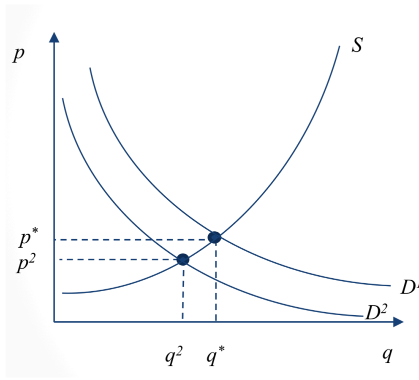

Figure 16: Shift in demand due to reputation risk

As seen in figure 17 there is a correlation between the price of inputs and the price of fish. Asche & Oglend (2016) argue that as a market matures, the market becomes more and more dependent on the prices of the input in terms of sale price, displaying a diminishing marginal productivity. Consequently, it is likely that future prices will be even more correlated with the price of inputs, and especially feed in the case of the aquaculture sector. Climate related risks will therefore be of greater importance in the future, as it might increase the price of the raw materials. These risks are hard to terminate as of now, due to lack of substitution possibilities, however, from a risk management perspective, the businesses should asses the problem, and look for possibilities to control these climate risks. There is no unique solution to this problem, however each business should asses their risk exposure, and look for ways to control these risks. This may involve changing their long-term strategies to include sustainable feed development and ensuring that managers and the investors are giving these risks appropriate attention.

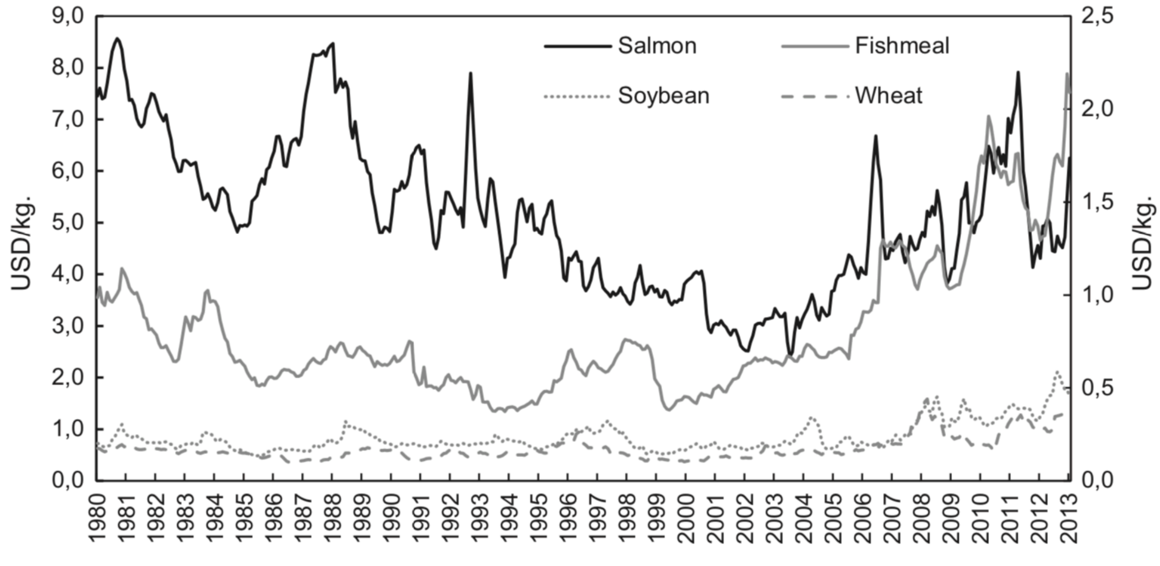

Figure 17: Input Prices and Price of Salmon (Asche & Oglend, 2016)

6.2 Labor Market

Development within aquaculture has focused around innovative solutions in relation to automatic production processes, which has made the sector more capital-intensive than labor-intensive. Where salmon farming seems the most industrialized production in the sector. From 1986 to 2013 registered companies fell from 224 to 91 companies. Simultaneously production increased from 28 t per person-year to 366 t per person-year, where labor cost decreased from 15 % to 8 % of unit production cost, but feed cost increased from 31 % to 51 % of unit production cost (Asche & Oglend, 2016). Nevertheless, aquaculture is a biological production process which makes dependent on labor due to protection of fish health. Observation of fish behavior, cleansing of pens, vaccination, research and development are some tasks that acquire labor.

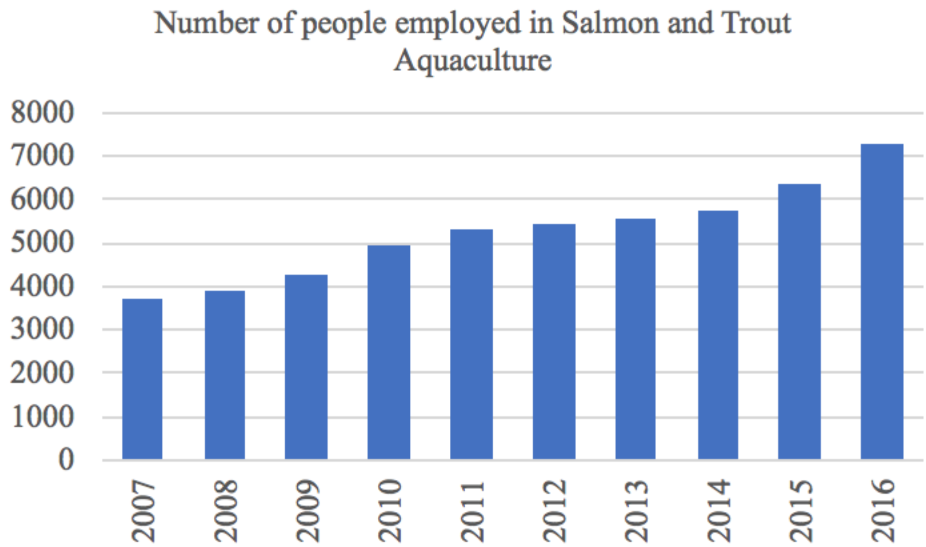

Figure 18: Number of People employed in Salmon and Trout Aquaculture (Statistics Norway)

Because of increased export prices, the aquaculture sector has experienced significantly increased profits the last years. This positive economic development gives the sector the opportunity to invest in core operations as well as expand to other parts of seafood industry, and this expansion indicates increased requirements for capital and labor. Aquaculture has become an international market with global competition, and today farmed salmon and trout are creating significant export values for Norway. The growth of salmon and trout farming has increased the amount workplaces along the Norwegian coastline, and as figure 18 illustrate, one can see that number of employed has had a significantly increase since 2007.

The Norwegian labor market is characterized by low unemployment rates and high wages, increased wages are explained through currency appreciation and higher productivity among workers and firms. Because of high wage rates as well as high education among employees, they have the tendency to choose their workplace based on wages and compensations. Accordingly, the sectors are exposed to competition in the market for labor. The oil and gas industry has occupied a big share of the labor force especially on the west coast of Norway, but the global intension to tackle climate change indicates that there will be a slowdown of fossil fuel. Consequently, other sectors will be taking over the labor force to maintain the socioeconomic gain from export. It can be argued that the aquaculture sector would to some extent utilize this available labor, because; (1) increased demand for seafood leading to growth in the sector (2) seafood is the second largest exported good, after oil and gas, (3) similar knowledge, such as marine and offshore competence.

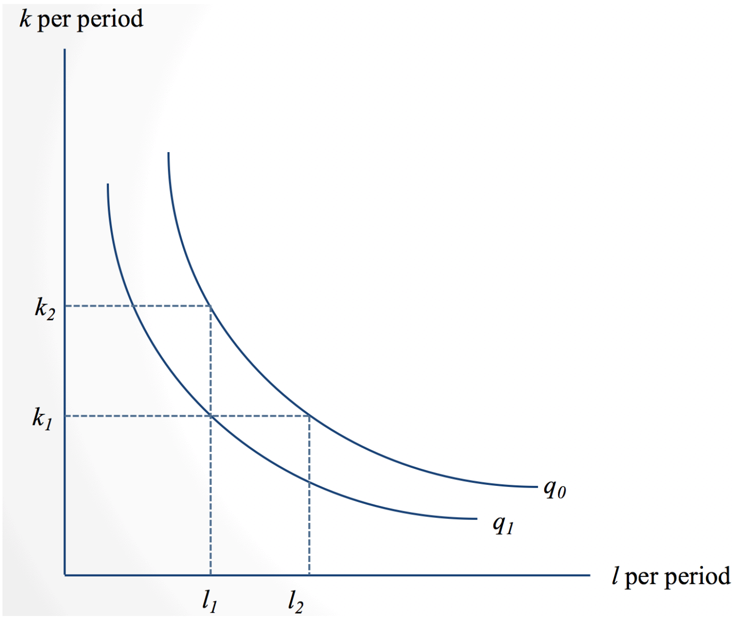

Figure 19: Technical progress

Today's challenges linked to fish diseases, lice and marine resource dependency slows down the growth potential. As mentioned global warming may also intensify these challenges. Thus, the sector needs highly educated people to come up with innovative solutions. Methods of production has already been improved, but continuing improvements could push the production function further towards the origin, as illustrated in figure 19. The technical progress then causes a shift (from q_0 to q_1) which makes the sector able to produce same level of output but with fewer inputs. Because of low cost exporters, Norwegian aquaculture sector should also maintain the development of automation to preserve competitiveness. As the sector, has been exposed for regulation because of environmental considerations and fish health, it can be imagined that the sector still is a victim for such regulations. In order to maintain the growth within the sector it is important that regulation set by Norwegian authority do not go beyond environmental sustainability and competitiveness, if so it would become even less attractive for talented employees (Asche et.al, 2012).

Illustrated in figure 18, one can see that the number of employee almost doubled from 2007 to 2016. Due to increased demand for educated labor, shift towards a low-carbon economy, and growth in the sector, one might expect a continuing increase of employment within the aquaculture sector. Although technological innovation triggered a decrease in percentage share of labor cost per unit produced it has been steady from 2008 to 2016, as previously shown in figure 13. This trend of labor cost share can be explained through a slowdown in marginal productivity. Climate-related issues can affect organizations' future strategy and structure. In order to achieve a technical progression with respect to climate-related risks, organizations within the industry should change their strategy, business and financial planning. Therefore, there should be a common interest among the board and employees that further technological development should treat the challenges aquaculture faces.

6.3 Product Market

As described earlier the marketplace for seafood has changed rapidly after aquaculture become a standardized production method. The traditional fish market has been replaced by retail chains, and transactions are done through contract arrangements. The market for seafood has also become a global market, being shipped across borders with trailers, ships and airplanes depending on product forms. When examining the product market, we will focus on how demand and supply for seafood might change due to climate-related issues. We will also use our findings from the input markets, i.e. feed and labor, to analyze how changes in these markets affect the market for end-products.

6.3.1 Climate-related Opportunities

United Nations has estimated that the world population will grow to become 9.8 billion in 2050 (United Nations, 2013). Consequently, the world will require a tremendous increase in food production. Since land-based agriculture require vast areas of land, and meat production seems to be more polluting, seafood would most likely become one of the most important sources of nutritious food in the future. Concurrently with increased need for food supply, there also exist a shift in consumer's behavior toward low-carbon consumption. This combination of market forces gives the aquaculture a better competitive position compared with other food producing sectors, resulting in increased revenues in the long run.

As clarified earlier the sector seem to be characterized as a capital-intensive sector. Technological improvements have resulted in significantly higher productivity, thereby increased production. Looking at figure 7, we can see that production costs decreased, which can be a result of resource efficiency increasing as resources per kilogram salmon produced was reduced. Higher production levels made sure for lower customer prices, thereby increased demand. The reduction in operational cost gave rise to increased production capacity, thereby resulting in increased revenues. This cost-efficiency could contribute to the effort to reduce emissions. Although resource efficiency creates the ability to reduce operational cost, the marginal productivity started to slow down which again made sector more input-driven, which means that production cost depends on the variation in input-prices.

Due to the aquaculture sectors use of fossil fuels, both for transportation and electricity generation, this serves as an opportunity for improvement. A shift to lower carbon intensive energy sources could potentially reduce exposure for fossil fuel price increases, as well as get reputational benefits and support among investors. This could also potentially increase the sectors resilience, which again might help to smooth the transition towards a less carbon intensive economy. Consequently, operation costs could be lower, and the price for the consumer would likely decrease. Increasing profits during recent years has given the opportunity to increase investments, which means that they also have the opportunity to invest in more environmental friendly capital.

6.3.2 Climate-related Risks

Due to Norway's geographic location we are less prone to acute physical risks than other countries. Nevertheless, foreign located facilities and transport networks could be vulnerable to natural disaster causing supply chain interruptions. Physical chronic climate risks in the aquaculture are increased water temperature, raised sea level and ocean CO_2 acidification. These risks might be important in the long-run, and potentially be tackled by genetic engineering, making the fish more resilient. Our findings suggest that transition risks are of more importance than physical risks, where changes in regulations, technology, market and reputation appears to have a more significant impact on the industry.

The Norwegian government anticipate a fivefold increase in aquaculture production in the future, which means that more focus on sustainable growth and environmental impacts is necessary. Salmon lice and escapes seems to be the largest contributor of emission for the aquaculture, which has led to stricter regulations and reporting requirements already. Regulations and policies have also included the use of medication, permits to produce, green concessions and the "traffic-light" system. Aquaculture seems to be a victim of regulations, however for the Norwegian aquaculture appropriate regulations has made it possible for the sector to grow. The global initiative to curb emissions may lead to stricter climate policies, suggesting that there will be an increase of regulations for the aquaculture as well. This might have implications for chosen modes of transport. This will also affect the state of which the fish is transported, potentially reducing the possibility of fresh exports because of distance to delivery.

Through efficient climate regulations the oil and gas revenues in Norway are likely to be reduced. Government revenues must therefore be received from other sectors and industries. High export values, profitability and the values of concessions makes the aquaculture a good candidate for taxations. Norwegian authorities have suggested a resource rent tax on the salmon aquaculture, which includes salmon, trout and rainbow trout, and planned introduction is in 2020. Today, both petroleum and hydropower industries are taxed because of the utilization of natural resources, and a properly designed tax rate on aquaculture could benefit the Norwegian society. However, by introducing distortionary taxes the growth in the aquaculture sector could potentially slow down, making it less profitable, and thereby decrease investments. This could eventually result in movements of production and investment to either land-based production or cross borders.

Challenges and risks related to fish diseases, lice and raw material dependency already exist within in the sector. These challenges in a combination with emerging risks due to the transition to low carbon economy, forces the aquaculture to invest in innovation and technology. Early retirement of existing assets, as well as research and development would therefore cause expenditures to increase in the short run. However, companies that ignores the transition to new practices and processes will not meet stakeholders' expectations and consequently loose support among investors and banks, resulting in bigger financial loss.

Stricter regulation contributes to increased operational cost, while investments of technology supporting the transition to lower-carbon economy contributes to decreased operational costs in the long-run. However, market risks like changing customer behavior and increased cost of raw material may provide the grandest financial impacts. From a demand perspective, higher fish consumption per capita is likely to increase to cope with world population growth, food scarcity and low-carbon consumption. Changing input prices could potentially lead to decreased demand as a result of higher prices of end-product. As discussed, this effect will also depend on the price transmission from price of raw salmon, to the end product-price. Climate related-risks caused by market changes is a complex issue with contradicting outcomes, making it hard to predict exact results.

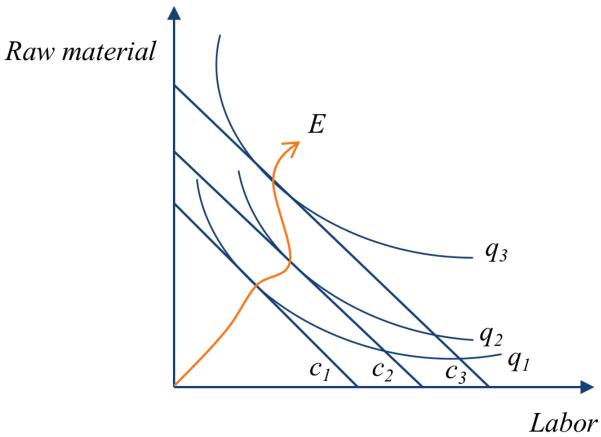

Figure 20: Cost-minimization for the producer

From figure 20 we can see the cost-minimization process for each level of output (q^1, q^2, q^3). The expansion path (*E*), shows that as production quantity increases, the input mix changes in order to produce at the cost-minimizing level (the intercept between isoquants and cost curves (c^1, c^2, c^3)). The shape of the isoquants, and thereby the cost-minimizing combination of labor and raw materials will depend on the availability, cost and necessity of inputs. At some production levels, cost minimization could require more units of raw materials than labor, in this case this is illustrated by the leftward move of the expansion path.

After examining the feed market our findings indicate that the development of input price of feed is likely to continue to increase as a result of climate risk, lack of substitutes, dependency and scarcity of the input materials. As the sector appear input driven, and feed constitutes a large fraction of total cost, an increase in its price would most likely push the total cost per kilogram produced upward. We are therefore going to represent a model of this movement, the model would however be a simplification of the reality as the size of the shifts would depend on the importance of the input, as well as the substitution possibilities that are available. We have chosen to depict the price as linear because most of the fish is sold at spot-price, making the producers price-takers. The possibility of manipulating prices by changing supply is not represented by this model.

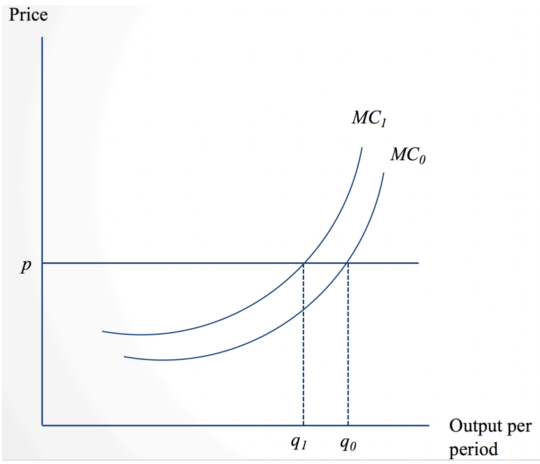

Figure 21: Profit maximization and input demand

If there was to be an increase in the price of feed, a new combination of the inputs would be chosen in order to minimize cost. If the output level where to be held constant, feed would be substituted for other inputs. Nonetheless, the dependency on feed in the production process would not make this possible, neither is it correct to hold output level constant as firms produce as much as the available demand allows. Because of the change in relative input cost there would also be a shift in firms' expansion paths, and consequently the cost curves would change. An increase in feed price would therefore cause marginal cost to shift upward, forcing the level of output to fall (from q_0 to q_1) as represented in figure 21. Since the rise in price of feed is industry wide, all firm's marginal cost curve would shift inward. This would cause supply to decrease (i.e. decreased output level), which again results in increased price as demand is downward sloping.

Labor has almost doubled since 2007, even so, it remained about 6 % of total production cost in the same period. This means that the cost of labor has not increased more than the average increase in production costs in the same period. During the same period feed costs remained at around 50 %, even though there was a reduction in share of costs from 53 % to 48 %. These numbers suggest that feed price is both the most vulnerable for climate risk, and at the same time the biggest share of production cost, meaning the production is more sensitive to changes in the feed- market than the labor market.

As we saw earlier reputational issues can impact demand both locally and globally. These types of demand fluctuations are usually short-term, so there are rarely significant long-term implications. Hence, there are usually no long-term financial impacts of reputational damage, as long as the sector has an appropriate risk response. Implementation of certifications, such as the ASC, might increase demand for sustainably farmed salmon. This suggests a decrease in demand for firms that are uncertified. Pressure to become certified could therefore become a transition risk for the firms. Most major producers in the farmed salmon sector in Norway are either members of the Global Salmon initiative, who have agreed to become a part of the ASC certification, or are already ASC- certified (ASC, W.Y.; Global Salmon Initiative, W.Y.). This could also provide a competitive advantage for the Norwegian salmon, thereby increasing global demand for responsibly farmed salmon.

Both the physical and transition risks could potentially affect the product market financially. How they affect the businesses within the market will depend on several factors, such as the degree of integration and their risk management. Businesses should be aware of the potential impacts for their business, by providing disclosures of climate risk for both consumers and investors. These should reflect the attention given to climate risk, how their long-term strategy might be affected, and how they are prepared to deal with the implications. This will increase the financial stability, both for the business and the sector in the long-run, due to decreased uncertainty around investments.

6.4 External Conditions

In this section of the analysis we are going to study some external conditions for the aquaculture, where external conditions refer to social, economic and ecological factors that affect the activity within the sector, and that is not under direct control of companies. The

Norwegian aquaculture is exposed to competition both at a national level and an international level. Competition at a national level arises from competition for labor and access to sea areas between sectors/industries, while competition at an international level arises from increased competition from countries with lower wage rates and costs. Both nature and market have significant influence on the production process and production level for the aquaculture, and these conditions are essential in relation to the sector's growth. To maintain a sustainable development as well as keep the Norwegian aquaculture sector competitive, there are therefore some conditions that should be considered.

Aquaculture is dependent on nature. Large parts of the production process are currently located in sea areas which point out the need for a good aquatic environment, furthermore is the biological production process dependent on natural resources, which have become scarce. Input factors such as feed is produced by renewable resources but still highly dependent on sustainable management. Lack of knowledge related to population dynamics could lead to overuse of the marine resources thereby resulting in limited supply of raw materials to the industry. Government regulations would play an important role when it comes to controlling input factors and production level.

Market limitation is based on social and economic factors, and to maintain growth within the sector it has to be competitive related to customers, competitors, employees, investors and government preferences. All stakeholders have different expectations to the sector; the government requires sustainable development; customers have preferences for product and product price; employees want high wages and compensations; and investors want companies to be competitive and risk adjusted. Expectations from the stakeholders leads to different market powers beyond the sectors direct control. Global price competition (i.e. seafood, raw material and other input factors), global innovation competition in end products and new technologies, complex value chains and market entrance are examples of this (NOU 2014:16). Stakeholders have expectations of how sectors and firms handle climate change, which means that climate risks are going to develop a stronger role in the market conditions in the future. Production processes, end- products, innovative technologies and risk management must develop in line with environmental preferences and expectations from stakeholders in order to maintain support.

6.5 Investments

Due to high profits the last years, firms within the aquaculture sector have had the opportunity to invest in both core operations and other seafood markets. The lucrative position the industry has experienced has been caused by an increased global demand for seafood, and it is likely that the increasing demand is a continuous trend. The economic outlook for the sector depends on climate related risks which pose challenges for the sector. Namely challenges related to feed ingredients, climate policies and regulations. As we saw in figure 5 aquaculture production has not had a substantial increase since 2012 due to restrictions regarding fish lice and health concerns, furthermore the industry is vulnerable to price fluctuations. Production costs have also increased by around 60 % per kilogram from 2008 to 2016. Due to the uncertainty around growth potential and increased costs – one might expect that uncertainty around future investments has increased.

Uncertainty related to raw material costs and end-product prices in the future could potentially affect the current investment behavior of the companies. Since future production is dependent on investments taken today, the value of an investment must be attractive in order to be carried out. From a net present value perspective, increased production costs will decrease the value of future investments, making investments less attractive. Consequently, current investments would decrease. However, tackling the lice problem and increasing feed sustainability will require investments through both research & development and education. This could put pressure on the profitability of the sector in the short-run, but it is important to remember that investment taken results in a chain of other possible business initiatives in the future.

If a proposed tax on carbon emission or resource rent (which is of today already planned due to the slowdown in oil and gas revenues) were to be introduced, one can assume that the competitive situation for the Norwegian aquaculture worsens. Investments uncertainty could increase, and if all other things are held equal this might result in diversification, for example through acquisitions (i.e. vertical integration) or entering new markets (i.e. horizontal integration). As stated in the section about "2.2 Risk perception and risk behavior", decisions taken under uncertainty do not always correspond with the true probabilities of the outcome, as humans often allocate subjective judgements to the probabilities. The degree to which the actors feel affected by climate-related risks could influence their effort to respond to these risks, and because of underestimation of possible impacts, there is a chance that companies would take insufficient investments. Alternatively, unbalanced estimates of uncertainty combined with optimism could lead to even stronger effort to survive and thereby increasing activity, resulting in successful readjustment.

From a more forward-looking perspective investments could cause several other opportunities. Firms that make a commitment to tackle these risks, and invest thereafter, receive support among governments, banks and investors, thus improved collaboration. In the long run, this could potentially create a competitive advantage, as stakeholders choose those companies that adapt to tackle climate change. Experts anticipate that the increased environmental pressure might force increased investments and thereby increase production cost in coming years (Misund & Tveterås, 2018). This is in line with our expectations regarding the implications of climate risk. In the long-run the implications might be increased efficiency, more sustainability and therefore increased production, thus increased profits.

The overall impression of our findings is that investments in the future are going to have the same development as in recent years, because of increased environmental pressure, stricter policy and regulations. However, from a risk management perspective there exists risks that potentially could affect the investment behavior. The implications of climate risk presented in this thesis are general, and not firm specific. This means that investment decisions should be based on objective assessments of the specific firms' exposure to climate risk, and not general expectations.

7. Conclusion

The purpose of our analysis has been to disclose climate risks and opportunities, and their respective implications for the Norwegian aquaculture sector. In our analysis, we have used previously written literature regarding estimated implications of climate change, with respects to both physical and transition risks. Further we have studied how these identified risks might impact specific areas of the sector, such as feed-market and labor market among others. We then analyzed their collective implications for the product market using a microeconomic perspective. In order to evaluate external forces, we also briefly analyzed the external conditions in which the sector is dependent upon. In order to capture future expectations, we also studied the effects of climate risk on investments.

Our findings suggest that transition risks are most significant for the sector, especially in the short- to medium-term. Policy changes and restrictions in terms of raw material usage due to scarcity seem to be the most prominent of these risks. Consequences in the short-run will most likely be a continued increase in production costs, and limited growth in production due to policy and regulation. Physical risks seem less important, especially in the short to medium term. Over time, acute and chronic risks may have impacts, however these effects are hard to estimate.

Recommendations for the producers would be to do an assessment of their own production processes in terms of climate risk and opportunity. Some producers have highly integrated value chains and are in control of much of their supply chain; from feed production to distribution and sale of finished goods. Others are dependent on external suppliers, and thus have less control of the processes. Therefore, there is no unique solution for all of the producers. By doing an objective assessment the businesses would allow the firms to take advantage of risk management techniques, in order to determine whether the risks are to be terminated, treated, transferred or tolerated.

The producers should objectively disclose their assessment of climate risk; with respect to their; governance, strategy, risk management, and metrics and targets. Providing information and calculations around how the identified physical and transition risks affect each of these concepts would reduce financial risks both for the businesses, investors and the sector in the long-run. Further we believe this information should also be available to the public. In this way consumers could also expand their knowledge around companies' adaption to climate risks.

Recommendations for governing institutions would be to take advantage of expert knowledge. Even though programs like "traffic-light" is a step towards taking environmental issues into consideration, the boundary between expert knowledge and political considerations ought to be more differentiated. Sustainability should be the main goal, and thus expansion and production should follow, so that the Norwegian society can benefit from these resources also in the future. Resource rent taxation could be an advantage for the Norwegian society, however it should be implemented in a way that does not harm the growth potential of the sector.

Our thesis is based on the broad concept of climate risk; thus, the analysis offers limited in-dept analysis of the specific parts of the sector. Further, the thesis does not provide quantified implications of the climate risk. This could be seen as a weakness of the analysis, although our goal was to capture climate risks the sector is facing throughout the value chain. The thesis was challenging in its nature because of the biological and environmental information requirements. As a result, there is a possibility that some of these effects are not captured in their entirety due to our economic approach. This might have affected the physical risk section. Further the boundary between environmental risks and physical climate-risks can due to their nature be hard to differentiate and can in some cases affect one another.

Further research should be pursued both when it comes to the impacts of the physical risks and expectations for transition risks. A subjective assessment by the sector regarding their vulnerability towards climate risk, and their efforts to mitigate and adapt to these changes would also reveal whether they regard climate risk as a financial threat.

8. References:

Abel, A. (1983). Optimal Investment Under Uncertainty. *The American Economic Review, 73*(1), 228-233.

Aggarwal, R., & Dow, S. (2012). Corporate governance and business strategies for climate change and environmental mitigation. *The European Journal of Finance, 18*(3-4), 311-331.

Akerlof, K., Maibach, E. W., Fitzgerald, D., Cedeno, A. Y., & Neuman, A. (2013). Do people "personally experience" global warming, and if so how, and does it matter?. *Global Environmental Change*, *23*(1), 81-91.

ASC (W.Y). *History.* Obtained from: https://www.asc-aqua.org/about-us/history/

ASC (W.Y). *Salmon.* Obtained from: https://www.asc-aqua.org/what-we-do/our-standards/farm-standards/the-salmon-standard/

ASC (W.Y). *Members.* Obtained from: https://www.asc-aqua.org/what-you-can-do/take-action/find-a-supplier/

Asche, F. (2008). Farming the Sea. *Marine Resource Economics, 23*(4), 527-547.

Asche, F., Roll, K., & Tveterås, R. (2012). FoU, innovasjon og produktivitetsvekst i havbruk. *Econa's journal for economics and management, Magma.*

Asche F., Roll, K., & Tveterås, R. (2009). Economic inefficiency and environmental impact: An application to aquaculture production. *Journal of Environmental Economics and Management, 58*(1), 93-105.

Asche, F., Roll, K., Sandvold, H., Sørvig, A., & Zhang, D. (2013). Salmon Aquaculture: larger companies and increased production. *Aquaculture Economics & Management, 17*(3), 322-339.

Asche, F., & Guttormsen, A. (2001). Patterns in the Relative Price for Different Sizes of Farmed Fish. *Marine Resource Economics, 16*(3), 235-247.

Asche, & Oglend. (2016). The relationship between input-factor and output prices in commodity industries: The case of Norwegian salmon aquaculture. *Journal of Commodity Markets, 1*(1), 35-47.

Austin, K. (2010). Soybean Exports and Deforestation from A World-Systems Perspective: A Cross-National Investigation of Comparative Disadvantage. *The Sociological Quarterly, 51*(3), 511-536.

Becker, S., & Brownson, F. (1964). What Price Ambiguity? or the Role of Ambiguity in Decision-Making. *Journal of Political Economy, 72*(1), 62-73.

Bernanke, B. (1983). Irreversibility, Uncertainty, and Cyclical Investment. *The Quarterly Journal of Economics, 98*(1), 85-106.

Binswanger, H.P. (1980). Attitudes toward risk: Experimental measurement in rural India. *American Journal of Agricultural Economics,* (3), 395-407.

Bo, H. & Sterken, E. (2007). Attitude towards risk, uncertainty, and fixed investment. *North American Journal of Economics and Finance, 18*(1), 59-75.

Brander, K. M (2007) Global fish production and climate change *International Council for the Exploration of the Sea, 44 – 46. Doi; 10.1073 pnas.0702059104*

Carney, M. (2015). *Breaking the tragedy of the horizon – climate change and financial stability.* Speech held in at Lloyd's of London in London. Obtained from: https://www.bankofengland.co.uk/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability

Carruth, A., Dickerson, A., & Henley, A. (2000). What do We Know About Investment Under Uncertainty? *Journal of Economic Surveys, 14*(2), 119-154.

Cavallaro, Pearce, & Sidortsov. (2018). Decarbonizing the boardroom? Aligning electric utility executive compensation with climate change incentives. *Energy Research & Social Science, 37*, 153-162.

Cochrane, K., Young, C., Soto, D. & Bahri, T. (2009) Climate change implications for fisheries and aquaculture Overview of current scientific knowledge. *FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO. 2009. 212p*

Damodaran, A. (2012) *Investment Valuation: Tools and Techniques for Determining the Value of Any Asset.* Hoboken: Wiley

Dixit, R., & Pindyck, R. (1994). *Investment under uncertainty*. Princeton: Princeton University Press.

Datamonitor. (2010). *Palm Oil Case Study, How consumer activism led the push for sustainable sourcing.* London: John Carpenter House

Ellingsen, Olaussen, & Utne. (2009). Environmental analysis of the Norwegian fishery and aquaculture industry—A preliminary study focusing on farmed salmon. *Marine Policy, 33*(3), 479-488.

Ellis, R., Urbina, M., & Wilson, R. (2017). Lessons from two high CO 2 worlds – future oceans and intensive aquaculture. *Global Change Biology,23*(6), 2141-2148.

Ficke, A., Myrick, C. & Hansen, L (2007) Potential impacts of global climate change on freshwater fisheries *Rev Fish Biol Fisheries (2007) 17:581–613. DOI: 10.1007/s11160-007-9059-5*

FSB. (without year). *About FSB.* Obtained from: http://www.fsb.org/about/

Gachango, Ekmann, Frørup, & Pedersen. (2017). Use of pig by-products (bristles and hooves) as alternative protein raw material in fish feed: A feasibility study. *Aquaculture, 479*, 265-272.

Gaspars-Wieloch, H. (2017). Project Net Present Value estimation under uncertainty. *Central European Journal of Operations Research*, 1-19.

Grothman, T. & Patt, A. (2005). Adaptive capacity and human cognition: The process of individual adaption to climate change. *Global Environmental Change 15 (2005) 199–213.* Doi; 10.1016/j.gloenvcha.2005.01.002

Global Salmon Initiative. (2018). *GSI Members.* Obtained from: https://www.asc-aqua.org/what-you-can-do/take-action/find-a-supplier/

Gruben, M., H. (2007). *Etterspørsel Etter Laks : Når Negativ Medieomtale Påvirker Salget Av Laks*.

Gjedrem, T. (2012). Genetic improvement for the development of efficient global aquaculture: A personal opinion review. *Aquaculture, 344*, 12-22.

Giskeødegård, K. (2014). Norske sjømatselskaper som investeringsobjekter. *Praktisk økonomi & Finans,* (02), 143-159.

Handisyde, N. T., Ross, L. G., Badjeck, M. C., & Allison, E. H. (2006). The effects of climate change on world aquaculture: a global perspective. *Aquaculture and Fish Genetics Research Programme, Stirling Institute of Aquaculture. Final Technical Report, DFID, Stirling. 151pp*.

Hartman, R. (1972). The effects of price and cost uncertainty on investment. *Journal of economic theory*, *5*(2), 258-266.

Hopkin, Paul. (2013). *Risk Management* (1st ed., Strategic success series. 0). Kogan Page.

Hovland, E., Møller, D., Vik, S. (2010) Fortellinger om kyst-Norge. *Åkeren kan òg være blå: Et riss av havbruksnæringens utvikling i Norge* (Vol. [6], Fortellinger om kyst-Norge). Oslo: [ABM-utvikling].

Huettel, Stowe, Gordon, Warner, & Platt. (2006). Neural Signatures of Economic Preferences for Risk and Ambiguity. *Neuron, 49*(5), 765-775.

IEA. (2017). *World Energy Outlook - Executive summary.* Obtained from: https://www.iea.org/Textbase/npsum/weo2017SUM.pdf

Institute of Marine research. (2016) *Risikovurdering norsk fiskeoppdrett 2016.* Vol. 2-2016, Fisken og havet. Bergen: Institute of Marine Research

Jahn, G., Schramm, M., & Spiller, A. (2004). Differentiation of Certification Standards: The trade-off between generality and effectiveness in certification systems. In *IAMA's 14th World Forum and Symposium, Montreux, Switzerland, June*.

Jordal, Anne. (2014) Laksebørsen FishPool. *Praktisk økonomi & Finans,* (02), 160-167

Jortveit, A. (2017, 23th November). Martin Schanke mfl. Om ekspertutvalget og statens klimarisiko [Blog post]. Obtained from: https://energiogklima.no/blogg/kl-1830-direkte-pa-klimatv-no-hor-martin-skancke-mfl-om-ekspertutvalget-og-statens-klimarisiko/

Karlsson-Drangsholt, A., Nes, S. (2017) Miljøkonsekvens analyse: Integrert havbruk i Norge. September 2017. (Bellona report).

Kumbhakar, S., & Tveterås, R. (2003). Risk Preferences, Production Risk and Firm Heterogeneity*. *Scandinavian Journal of Economics, 105*(2), 275-293.

Kvaløy, O., & Tveterås, R. (2008). Cost Structure and Vertical Integration between Farming and Processing. *Journal of Agricultural Economics, 59*(2), 296-311.

Landazuri-Tveteraas, U., Asche, F., Gordon, D., & Tveteraas, S. (2018). Farmed fish to supermarket: Testing for price leadership and price transmission in the salmon supply chain. *Aquaculture Economics & Management, 22*(1), 131-149.

Leck, H., & Simon, D. (2013). Fostering Multiscalar Collaboration and Co-operation for Effective Governance of Climate Change Adaptation. *Urban Studies, 50*(6), 1221-1238.

Lusedata (W.Y.) *Slik sikrer vi kontrollen med lakselus.* Obtained From: http://lusedata.no/tiltak/

Marine Harvest (2017) *Salmon Farming Industry Handbook.* Obtained From: http://marineharvest.com/investor/industry-handbook/

Marine Harvest (2018) *Integrated Annual Report 2017 Leading the Blue Revolution.* Obtained From: http://hugin.info/209/R/2177429/840178.pdf

McDonald, R., & Siegel, D. (1986). The Value of Waiting to Invest. *The Quarterly Journal of Economics, 101*(4), 707.

Mertzanis, C. (2013). Risk Management Challenges after the Financial Crisis. *Economic Notes, 42*(3), 285-320.

Misund, B., Tveterås, R. (2018) *To tax or not to tax, that is the question.* Obtained from: https://ilaks.no/to-tax-or-not-to-tax-that-is-the-question/

Mohd Noor, F. M., A. Gassner, A. Terheggen, and P. Dobie. (2017). Beyond sustainability criteria and principles in palm oil production: addressing consumer concerns through insetting. *Ecology and Society* 22(2):5. https://doi.org/10.5751/ES-09172-220205

Nordhaus, W. D. (2013). *The climate casino: Risk, uncertainty, and economics for a warming world*. Yale University Press

Norwegian Climate Foundation. (2017). *Klimastiftelsen oppsummerer 2017.* Obtained from: http://klimastiftelsen.no/klimastiftelsen-oppsummerer-2017/

Norwegian Directorate of Fisheries. (2017). *Grønne Tillatelser.* Obtained from: https://www.fiskeridir.no/Akvakultur/Tildeling-og-tillatelser/Kommersielle-tillatelser/Laks-oerret-og-regnbueoerret/Groenne-tillatelser

Norwegian Directorate of Fisheries. (2018). *Utviklingstillateser.* Obtained from: https://www.fiskeridir.no/Akvakultur/Tildeling-og-tillatelser/Saertillatelser/Utviklingstillatelser

Norwegian Directorate of Fisheries. (2018). *Akvakulturregisteret.* Obtained from: https://www.fiskeridir.no/Akvakultur/Registre-og-skjema/Akvakulturregisteret

Norwegian Directorate of Fisheries (2018). *Rømmningstatistikk.* Obtained from: https://www.fiskeridir.no/Akvakultur/Statistikk-akvakultur/Roemmingsstatistikk

Norwegian Directorate of Fisheries (2017). *Rensefisk.* Obtaines from: https://www.fiskeridir.no/Akvakultur/Statistikk-akvakultur/Akvakulturstatistikk-tidsserier/Rensefisk

Norwegian Government (2017). *Regjeringen skrur på trafikklyset.* Obtained from: https://www.regjeringen.no/no/aktuelt/regjeringen-skrur-pa-trafikklyset/id2577032/

Norwegian Seafood Council. (2018). *Nøkkeltall.*
Obtained from: https://sjomatnasjonen.seafood.no/wp-content/uploads/2018/01/utvikling-verdi-fiskeri-vs-havbruk.png

NOU 2014:16 (2014). *Sjømat industrien – utredning av sjømatindustrien rammevilkår.* Oslo: Norwegian Government Security and Service organization, information services. Obtained from:https://www.regjeringen.no/contentassets/b8395c5e287846c281e434173d733511/no/pdfs/nou201420140016000dddpdfs.pdf

Ou, M., Hamilton, T., Eom, J., Lyall, E., Gallup, J., Jiang, A., Lee, J., Close, D., Yun, S. & Brauner, C. (2015) Responses of pink salmon to CO2-induced aquatic acidification *Nature Climate Change 5, 950-955 (2015)* Doi: 10.1038/nclimate2694

Osmundsen, T., Almklov, P., & Tveterås, R. (2017). Fish farmers and regulators coping with the wickedness of aquaculture. *Aquaculture Economics & Management, 21*(1), 163-183.

Portelli, S. (2013). Probabilistic risk, neuroeconomic ambiguity, and Keynesian uncertainty. *Journal of Post Keynesian Economics, 36*(1), 3-14.

Savage, L. J. (1972). *The foundations of statistics*. Courier Corporation.

Schwach, V., & Havforskningsinstituttet. (2000). *Havet, fisken og vitenskapen : Fra fiskeriundersøkelser til havforskningsinstitutt 1860-2000*. Bergen: [Havforskningsinstituttet].

Sjöberg, L. (1979). Strength of belief and risk. *Policy Sciences, 11*(1), 39-57.

Statistics Norway. (2017). *Table.* Obtained from: http://www.ssb.no/315340/sysselsatte-personer-etter-hovednaering.lonnstakere-og-selvstendige.1-000-sa-209

Stern, N. (2008). The Economics of Climate Change. *American Economic Review, 98*(2), 1-37.

Stien, Audun, S., Bjørn, Pål Arne, B., Heuch, P. A., H., & Elston, David A., E. (2005). Population dynamics of salmon lice Lepeophtheirus salmonis on Atlantic salmon and sea trout. *290*, 263-275.

TCFD. (2017). *Task Force on Climate-related disclosure.* Obtained from: https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-TCFD-Report-062817.pdf

TCFD. (2017). *Implementing the Recommendations of the Task Force on Climate-related Financial Disclosure.* obtained from: https://www.fsb-tcfd.org/wp-content/uploads/2017/12/FINAL-TCFD-Annex-Amended-121517.pdf

Torrissen, O., Olsen, R., Toresen, R., Hemre, G., Tacon, A., Asche, F., . . . Lall, S. (2011). Atlantic Salmon (Salmo salar): The "Super-Chicken" of the Sea? *Reviews In Fisheries Science, 19*(3), 257-278.

Troell, M., Naylor, R., Metian, M., Beveridge, M., Tyedmers, P., Folke, C., . . . De Zeeuw, A. (2014). Does aquaculture add resilience to the global food system? *Proceedings of The National Academy Of Sciences Of The United States Of Ame,111*(37), 13257-13263.

United Nations. (2013). *World population projected to reach 9.6 billion by 2050.* Obtained from: http://www.un.org/en/development/desa/news/population/un-report-world-population-projected-to-reach-9-6-billion-by-2050.html

Tvete, A. (2016). *An Approach to Salmon Farming in Norway : A Future for Land Based Salmon Farming?* (metathesis). Bergen: Norwegian School of Economics.

Van der Linden, S., Maibach, E., & Leiserowitz, A. (2015). Improving Public Engagement With Climate Change. *Perspectives on Psychological Science, 10*(6), 758-763.

Weber, Elke U., & Stern, Paul C. (2011). Public Understanding of Climate Change in the United States. *American Psychologist, 66*(4), 315-328.

Wong, J. & Schuchard, R. (2011). *Adapting to Climate Change: A Guide for the Food, Beverage, and Agriculture Industry.* BSR (Business for Social Responsibility) Obtained from: https://www.bsr.org/reports/BSR_Climate_Adaptation_Issue_Brief_Food_Bev_Ag2.pdf

Ytrestøyl, T., Aas, T., S., & Åsgård, T. (2015). Utilisation of feed resources in production of Atlantic salmon (Salmo salar) in Norway. *Aquaculture, 448*, 365-374.

Yue, & Wang. (2017). Current status of genome sequencing and its applications in aquaculture. *Aquaculture, 468*, 337-347.

Zachariadis, T. (2016). After 'dieselgate': Regulations or economic incentives for a successful environmental policy? *Atmospheric Environment, 138*, 1-3.

Ziegler, F., Winther, U., Hognes, E., Emanuelsson, A., Sund, V., & Ellingsen, H. (2013). The Carbon Footprint of Norwegian Seafood Products on the Global Seafood Market. *Journal of Industrial Ecology, 17*(1), 103-116.