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Resource Rent in the Norwegian Aquaculture Industry

A bottom-up approach

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Simon Flatebø Selle

Abstract

This thesis investigates the generation of resource rent in the Norwegian aquaculture industry during 2010-2017. Whereas past empirical research on resource rent assumes that the license holder captures the entire rent, this thesis analyzes rent by also allowing for rent generation in other parts of the value chain. I develop an appropriate model based on a standard definition of economic profit from the economic literature. Using firm-specific accounting data on more than seven hundred companies from 2010 to 2017, I find that the industry generates substantial resource rent. Specifically, the results indicate a total resource rent of NOK 74.9 billion over the period, where 70.5 accrues to the license holders, and the remaining 4.4 billion accrues to other parts of the value chain (floating prices). License holders benefit greatly from exclusive access to high-quality natural resources, whereas the remaining parts of the value chain profits from a strong demand for goods and services, mostly driven by biological challenges in the farming operations.

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1. Introduction

Norway has a proud tradition of leveraging the commercial potential of its natural resources to benefit the public. As a result, it consistently ranks among the world's richest and best places to live (Lange et al., 2018). Historically, the most important resource industries have been forestry, fisheries, and hydropower. In the late sixties, Phillips Petroleum (now ConocoPhillips) drilled the first successful oil well on Norwegian soil, and petroleum has been the most important resource ever since. However, at the same time, Norway has also built a considerable aquaculture industry. In fact, Norway is the second largest aquaculture exporter in the world measured by value (FAO, 2018). The most common species are Atlantic salmon and rainbow trout.

Aquaculture production relies on natural resources, e.g., clean water and designated areas. In addition, it depends on the ecosystem's ability to handle increased biomass with the implications that follow, e.g., waste products, procreation of parasites, diseases, etc. Economists often call these implications "externalities". All the resources, including the ecosystem, is common property and belong to the public. The problem with most common property resources is that resource users (farmers) do not account for the externalities. Thus, they have an incentive to use more of the resource than what is socially optimal, known in the economics literature as "tragedy of the commons". The tragedy is simply the long-term consequences of short-term overexploitation. In order to curb externalities, authorities often impose regulations. The Norwegian government has introduced many precautionary restrictions, such as maximum allowed lice levels, systematic fallowing, maximum stock density in pens, licensing, etc.

Licenses are a prerequisite for any aquaculture activity in Norway and regulate the maximum allowed standing biomass. The number of traditional permits has remained practically fixed since 2013 (DoF, 2019b), thus defining a quantity-sealing on both company and national levels. Legally enforced supply restrictions alter the free competition characteristics of the market and push prices up. As a consequence, established industry players can freely operate with abnormal margins without the threat of new entrants. The extraordinary profits that arise from the privileged access to exploit scarce natural resources carry the name "resource rent" in economic literature. Formally, it represents the economic profit from exploiting natural resources, i.e., it measures the net benefit from the resource by subtracting all accrued production costs, including the opportunity cost of capital, from the accrued revenue. By this definition, one can interpret the rent as the value of the resource. The magnitude of the rent is irrespective of the interpretation. In recent years, there has been a significant price increase of both salmon and rainbow trout driven by aggravated biological conditions in Chile. [1] For this reason, the resource rent has increased drastically and gained public attention. The essence of the ongoing debate is who should benefit from the resources.

The objective of this thesis is to quantify the resource rent in the Norwegian aquaculture industry during 2010-2017. I study this topic for two main reasons. First, to elucidate the benefit that accrues to the license holders. Second, to provide insights into the financial state of the industry. The results from the empirical analysis have significant policy implications, particularly in light of the ongoing debate of whether to impose a special tax on the industry.

An important assumption in most existing research, either explicitly or implicitly, is that the license holder captures the entire resource rent (Boadway and Keen, 2015). This assumption holds if the license holder is vertically integrated and controls all parts of the production process, or if the other parts of the value chain are perfectly competitive. However, most firms rely on suppliers of goods and services, and demand tends to change rapidly. Thus, the accounts of the license holder may not contain the full cost of carrying the resource to the market because demand shifts can cause temporary market unbalances. I develop a model that accounts for the full production cost, including the opportunity cost of capital, in all stages of the production process. Hence, I contribute to the literature by suppressing the need for this assumption by quantifying the rent in all divisions of the value chain. I term the rent in other parts of the value chain, rent shifting.

My thesis makes two main contributions to the existing literature. First, it provides a comprehensive bottom-up analysis of resource rent in Norwegian aquaculture. Second, to the best of my knowledge, this is the first study to quantify the rent shifting effects empirically. Thus, my study provides new insight into the natural resource rent generation process.

Based on data from more than 700 legal entities during 2010-2017, I find an accumulated resource rent of NOK 74.9 billion, out of which six percent is rent shifting. I also use the farming rent estimates to calculate the value of a license to NOK 139.9 million, or NOK 179.4 thousand per tonne of licensed capacity, which is very close to the average price of NOK 195 thousand per tonne paid in the most recent auction (DoF, 2018). This price estimate is intriguing because

[1] World's second largest salmon farming nation (see chapter 2).

it implies that the cost of new licenses equals the expected net present value of the resource rent in perpetuity.

There are few empirical studies on resource rent in the Norwegian aquaculture industry (see chapter 2). In fact, to the best of my knowledge, there is only one directly comparable study to date. Based on a sample of 68 percent of the registered farming firms in Norway, Flaaten and Pham (2019) estimate the resource rent in 2016 to NOK 15.774 billion, or NOK 18.57 per kilogram of sold fish. They rely on the vertical integration assumption mentioned above, and the comparable estimate from my analysis is NOK 18.50 per kilogram (19.72 when I include rent shifting). Further, they utilize the Faustmann framework and estimate the value of a license to NOK 138 million, or NOK 176 thousand per tonne of licensed capacity.

Greaker (2018) estimates the resource rent to NOK 27 billion in 2016. These results are preliminary and stem from ongoing research. He applies information from the national accounts of Norway and a cost of capital of four percent, which is half the cost of capital in Flaaten and Pham (2019). Adjusting the cost of capital in my model yields a comparable estimate of NOK 23.5 and 25.9 billion, without and with rent shifting, respectively.

Altogether, the Norwegian aquaculture industry benefits greatly from the protective regulations and generates substantial resource rent. This conclusion is gripping because it provides new insights into one of the central issues of the ongoing debate, namely whether there is resource rent in the industry. Furthermore, the analysis also provides evidence that the resource rent is not a recent phenomenon, as many claims.

The remainder of this thesis is structured as follows. In chapter 2, I introduce the business of aquaculture, including historical development and current trends. In chapter 3, I introduce the theoretical concept of resource rent, and I present a selection of relevant literature. In chapter 4, I present the analytical framework for my empirical analysis. Chapter 5 explains how I build my data set and show summary statistics on its content. Chapter 6 presents and discusses the empirical results. Finally, chapter 7 concludes the thesis.

2. The Norwegian Aquaculture Industry

The modern history of Norwegian aquaculture began in the mid-1950s but did not become commercialized until the late 1960s and early 1970s. The 60s and 70s are known as the pioneering era where collective effort and exchange of experiences were essential to solving the enigma of successful marine cultivation. Norway benefits from its long and fragmented coastline consisting of a vast number of islands, islets, and fjords that provide great protection against wind and waves from the open ocean. Combined with a high replacement rate of pure water at favorable temperatures, it provides superb biological and physical conditions for aquaculture production. The present industry includes fish, mollusks, crustaceans, echinoderms, and algae. The by far most important species is Atlantic salmon followed by rainbow trout, which accounts for about 94 and 5 percent of the total production, respectively (DoF, 2019b). Because of its relative importance, I limit the remainder of this thesis to only consider salmon and rainbow trout cultivation (henceforth aquaculture).

Atlantic salmon refers to the Salmo Salar species in the Salmonidae family. The fish is easily recognizable on its streamlined body with a dark blue top and shiny scales along the sides. Rainbow trout, on the other hand, refers to the Oncorhynchus Mykiss species in the same family. Rainbow trout exists in two basic forms as either resident or migrating. One often refers to the latter as steelhead. The fish resembles Atlantic salmon except for a less streamlined body and lots of dark spots along the sides. Both Atlantic salmon and rainbow trout (steelhead) are anadromous, which means they spend most of their lives in the sea but migrates to freshwater for reproduction purposes. Further, both species are cold-blooded animals and therefore does not rely on internal sources of heat for regulating body temperature. As a result, the fish are very efficient in both energy and protein retention compared to onshore animals. Also, the fish have substantially higher edible yield and lower feed conversion ratio than most other animal sources of protein, e.g., pork, poultry, lamb, etc. (Mowi, 2019)

This chapter is structured as follows. In section 2.1, I introduce the value chain and production cycle. In section 2.2, I present current production characteristics, including production costs. Section 2.3 covers commodity prices and markets. Section 2.4 reports important industry players. Section 2.5 describes the relevant parts of the regulatory framework. Finally, section 2.6 presents ongoing technological trends and developments in both the farming industry and the service and supplier industry.

2.1 The Aquaculture Value Chain

The salmon and rainbow trout production cycle takes approximately three years from start to finish and involves a wide range of sequential activities. In short, the process starts with roe (eggs) and ends up as fillets on dinner tables all over the world. Figure 1 divides the cycle into six phases, and the remainder of this subchapter elaborates on each step chronologically.

Figure 1. The Aquaculture Value Chain

Source: Bremnes Seashore AS (2017), Author

Every generation of fish starts with a careful selection of roe according to the farmer's preferences. Historically, preferences were simply which river the fish originated from, often based on the perception that rougher rivers fostered more robust fish (Svarstad, 2001). Today, owing to genomic selection and systematic breeding, preferences are more specific and include, e.g., meat quality and color, growth speed, improved immune system, sterility, etc. (Aquagen AS, 2019b). When the farmer has decided on the preferred genetical characteristics, the roe producer mixes the appropriate eggs with milt to initiate fertilization. The fertilized eggs spend the next seven to nine weeks under close surveillance in small freshwater incubation tanks. When the eggs are adequately robust, typically at the eye-roe stage,[2] they are ready for smolt production facilities in phase two of the production cycle.

At the smolt plant, technicians reinstate the roe to small incubation tanks. After approximately 500 degree days, the roe hatches to larvae. Subsequently, technicians transfer the larvae to large freshwater tanks where they spend the next six months. During this time, the larvae evolve to Fry, then Parr, and eventually undergo a metamorphosis termed "smoltification" to develop the ability to live in waters with high salinity. The growth process from larvae to smolt implies a

[2] When the embryo develops eyes that are visible from the outside as two black dots.

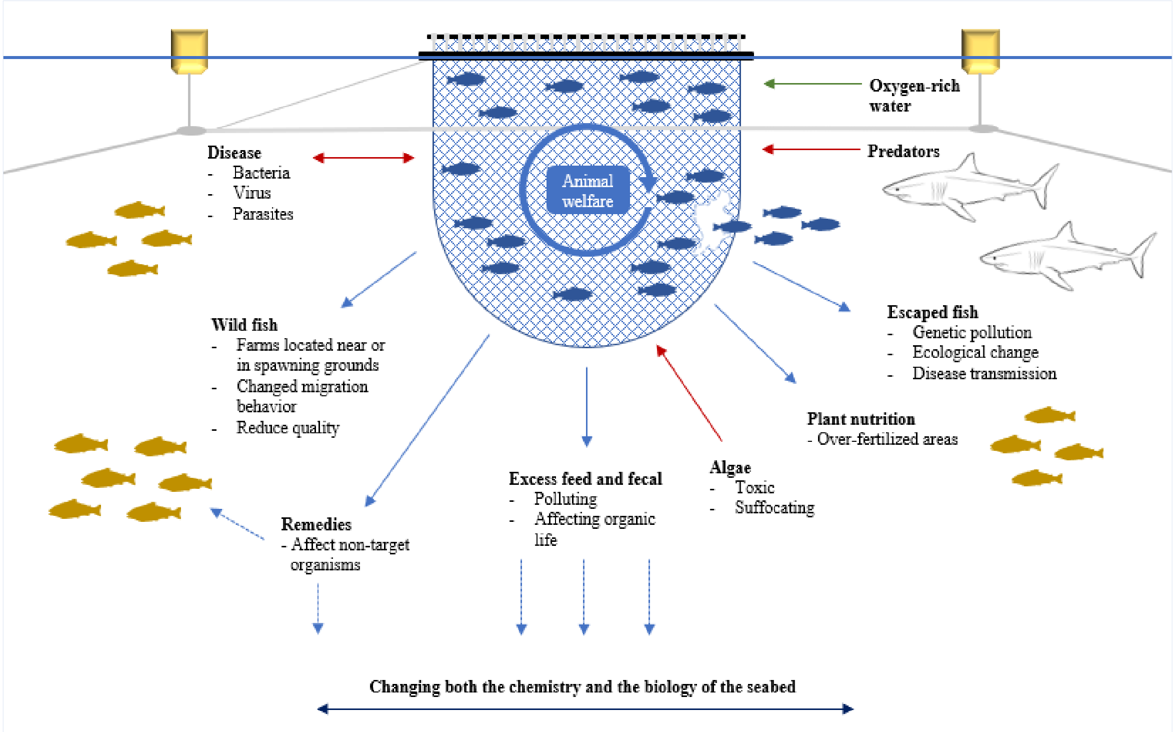
weight gain of about one hundred times the initial body weight. Normally, the fish weighs between 80 and 150 grams upon transfer to a life at sea.

Specialized fish-carrying vessels, commonly referred to as wellboats, transport the fish from the smolt facility to sea-based production sites, called localities. A typical locality consists of four to eight pens and a feed barge. Each pen is 120-200 meters in circumference and holds up to two hundred thousand individuals with a maximum fish density of 25 kilograms per cubic meter of water (Forskrift om drift av akvakulturanlegg, 2004). The barge contains silos and a feeding bridge where technicians carefully monitor appetite and control the feeding schedule accordingly. A typical feeding schedule suggests an appropriate portion size based on a function of growth rate[3], feed conversation ratio, and average fish size.

Present farming technology uses open-net solutions where water passes freely through the pen. On a company level, the open-net technology is beneficial since it does not require energy to supply new and oxygen-rich water. In addition, it utilizes water currents and thus does not require any systems to collect and handle waste, e.g., fecal, excess feed, remedies, etc. On the negative side, open-net technology is vulnerable to a wide range of externalities either from nature itself or from nearby localities, where transmission of parasites and diseases are the most common issues. In recent years, parasites (predominantly lice) have been a significant cost driver for the farming firms, see below. On a public level, the open-net technology puts substantial pressure on the ecosystem and its ability to process the careless release of waste and various medical remedies. Further, the farming pens provide ideal conditions for exponential procreation of parasites, which in turn negatively affect wild fish. Figure 2 illustrates the intricate relationship between the ecosystem and a fish pen. The direction of the arrows indicates the force of impact, and the sum of all variables define the animal welfare inside the net. For a detailed assessment of impacts, see Agnalt et al. (2018) (in Norwegian).

[3] Growth rate is a function of feed ingredients and temperature. Feed producers provide feed-specific growth tables with average fish size (y-axis) and temperature (x-axis).

Figure 2. Open-net technology and the ecosystem



Sources: Inspired by Agnalt et al. (2018).

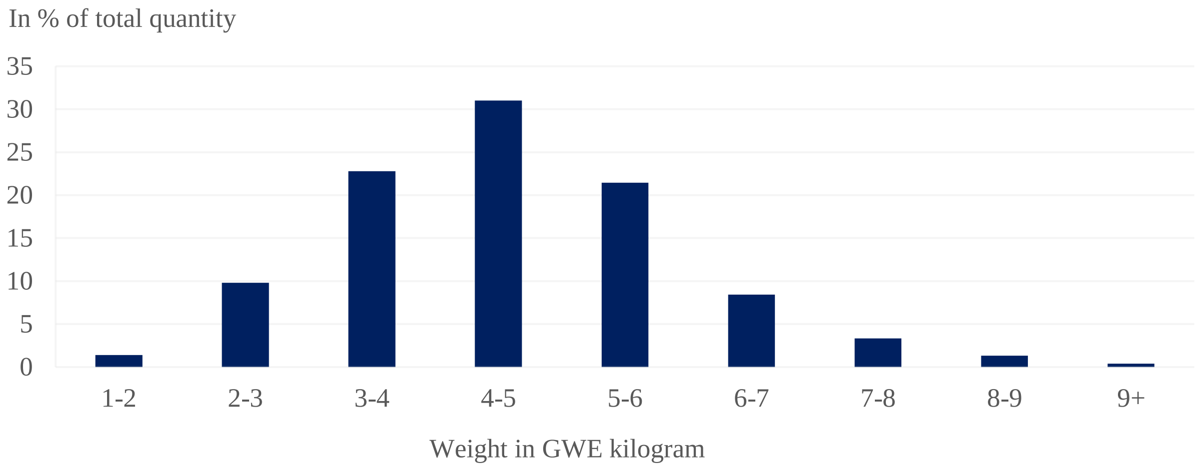
Owing to the constant threat of negative externalities, farmers keep the fish under close surveillance, and authorities demand weekly reports on, e.g., lice levels. When lice levels exceed a specific threshold, it requires mitigation actions.[4] Farmers have at least six options to cope with the lice issue. First, they can use medical remedies such as Alphamax, Betamax, or Salmosan. However, lice have developed medical resistance to several of them because of rapid procreation and strong adaptability (Helgesen et al., 2019). Second, they can apply non-medical treatment methods, e.g., Thermolicer, Optilicer, Skamik, or wellboats. These options work by pumping the fish through a rather complex machinery and either brushing the lice off (Skamik), use heated water that most lice cannot survive (Thermolicer and Optilicer), or expose the lice to freshwater (wellboats).[5] Although the methods have a reasonable efficiency, they inflict severe stress and discomfort upon the fish with associated elevated mortality (Hjeltnes et al., 2019). Besides, they require significant manual labor and large investments in equipment. A third method is to use medical feed, e.g., slice. Slice involves adding a substance to the feed pellets (emamectin benzoate), which the fish absorbs and distributes to its tissue. Subsequently, when a louse attaches to the fish and starts eating from the skin, the substance paralyzes the

[4] The threshold is set to an average of 0.5 female ovigerous lice per fish (minor seasonal variations), see 2.5 laws and regulations below.
[5] Some wellboats carry mechanical solutions in addition to the ability to treat with freshwater.

louse by blocking nerve impulses, and it dies (MSD Animal Health AS, 2012). A fourth method is to release cleaner fish, e.g., lumpfish, wrasse, etc. into the pen to eat the lice. This approach is becoming increasingly popular amongst farmers, and the industry releases about fifty million cleaners into the pens annually (DoF, 2019b). A fifth method is to use chemicals, such as hydrogen peroxide. Although this method has a rich tradition, farmers rarely use it today because of its potentially damaging effect on wildlife (Agnalt et al., 2018). The sixth and last method is an early harvest, which farmers generally regard as a last resort due to high alternative costs.

After 14 to 22 months at the locality with frequent treatments and daily care, the fish is ready for harvest with an ideal weight of close to five kilograms. Figure 3 depicts the average weight distribution of sold fish in 2018 measured in gutted weight equivalents (GWE)[6].

Figure 3. Size distribution in 2018



Sources: NASDAQ (2019)

A wellboat carries the livestock from the locality to a processing plant where it deposits the fish into holding pens or directly into the factory. The former is a small pen situated in direct connection to the factory where the fish stays for approximately 24 hours to de-stress from transportation. De-stressing is important to lower the levels of lactic acid and cortisol, which results in improved meat quality (Skjervold et al., 2001).

The first step of the processing phase is to transfer the fish into one or several large chilling tanks filled with cold water. In the chilling tanks, the fish adapts to the cold water and further

[6] Gutted weight equivalent is a standardized weight measure set forward by NS9417:2012, and represents the weight of a whole fish emptied for blood and entrails.

lowers its stress levels, which in turn delays the onset of rigor mortis[7] and is particularly important for filleting later-on. Following the chilling tanks, the fish continue into the slaughtering machines, where it receives a sharp blow to the head combined with cutting the main artery located behind the gills. Then the fish bleeds out to remove any blood from the tissue. The final step of the initial processing phase is gutting, which implies the removal of entrails and flushing of the meat, followed by a quality grading. Each fish receives a grade as either superior (best), ordinary, or production-grade (worst), based on several criteria, e.g., melanin spots, scale loss, coloring, deformation, wounds, etc. The grade ultimately determines the price, see below. One typically refers to the weight of the gutted fish as "gutted weight", which is the preferred unit of measurement used throughout this thesis. The entire process up to this point, including packaging of the gutted fish, is known as primary processing, and everything that follows is known as secondary processing.

Secondary processing includes any value-adding activity and appears in a wide range of formats. Typically, secondary processing involves the removal of the head and tail, filleting, and trimming (Johansson, 2017). Then the fish is prepared as, e.g., fillets with or without skin, loins, smoked, burgers, and so forth.

The final step of the production cycle is sales. Norwegian farmers export about 95 percent of the domestic production, mostly as gutted fish whole fish (Mowi, 2019). As a result, one can eat Norwegian farmed salmon and rainbow trout in most parts of the world, see below.

This concludes my brief introduction to the value chain of Norwegian salmon and rainbow trout aquaculture. The most important takeaway is the understanding of externalities in the farming phase and the interrelationship between farming and the ecosystem. Also, it is important to note the length of the production cycle with the implications that farmers decide future volumes three years in advance. I now proceed to present some key characteristics of the industry with an emphasis on the farming phase.

[7] Known as death stiffness where muscles tighten because of chemical changes in the tissue.

2.2 Production Metrics

The global production of salmon and rainbow trout in a marine environment reached 2.5 million tonnes in 2017, up from 1.7 million tonnes in 2010. Table 1 reports the eight largest producers in the world, and the relative magnitude of Norway is evident. In fact, Norway typically produces approximately half of the global supply and almost twice the quantity of the second largest production nation, Chile. Although I focus on Norway exclusively in the remainder of this subchapter, it is essential to note that Norway is the largest but not the only producer in the world.

Table 1. Global production of Atlantic salmon and rainbow trout in a marine environment

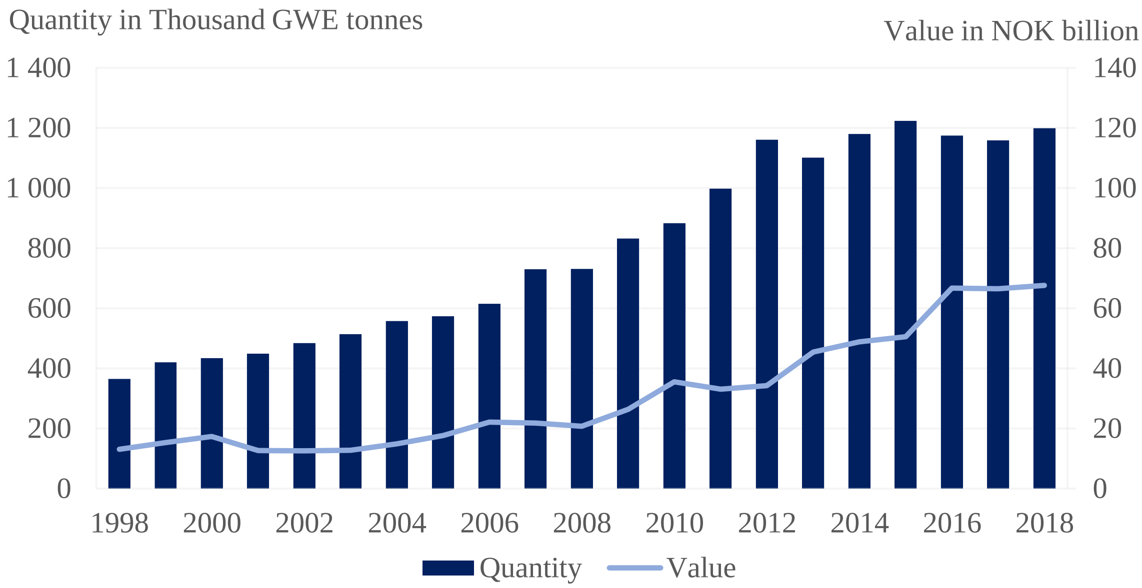
Country	2010	2011	2012	2013	2014	2015	2016	2017
Norway	994	1123	1307	1240	1327	1376	1321	1303
Chile	320	463	610	602	754	703	616	688
UK	156	159	165	165	181	177	167	193
Canada	102	110	116	98	86	122	124	122
Faroe Islands	48	60	77	76	86	81	83	87
Australia	32	37	44	43	42	48	56	53
US	20	19	19	19	19	19	16	15
Ireland	16	13	13	9	9	13	16	18
Others	24	30	25	45	37	31	31	34
Total	1 711	2 014	2 375	2 297	2 542	2 570	2 431	2 513

Notes: These are the only figures reported as whole fish equivalents (WFE) in this thesis.
Source: FAO (2019)

Figure 4 depicts the development of both output volumes and the corresponding value of Norwegian production during the last twenty years. Production and value have increased twofold and fourfold, respectively. At the same time, the aggregate global production volume has soared by more than 200 percent (FAO, 2019). Consequentially, the industry has been highly successful in developing new markets and extracting latent demand to cope with the production growth.

Although improved production technology, including any biotechnology, has been the main driver behind the supply growth, one must also credit the regulatory framework. There are numerous examples of failed aquaculture industries around the world where the authorities suppressed the need for sustainability, or simply was unwilling to take the risk of establishing a new biological industry (Asche and Bjørndal, 2011, Asche et al., 2014). In recent years, one must also ascribe some of the value development to a weak Norwegian krone (NOK).

Figure 4. Quantity and value of sold fish, in constant 2018 prices



Source: DoF (2019b), SSB (2019)

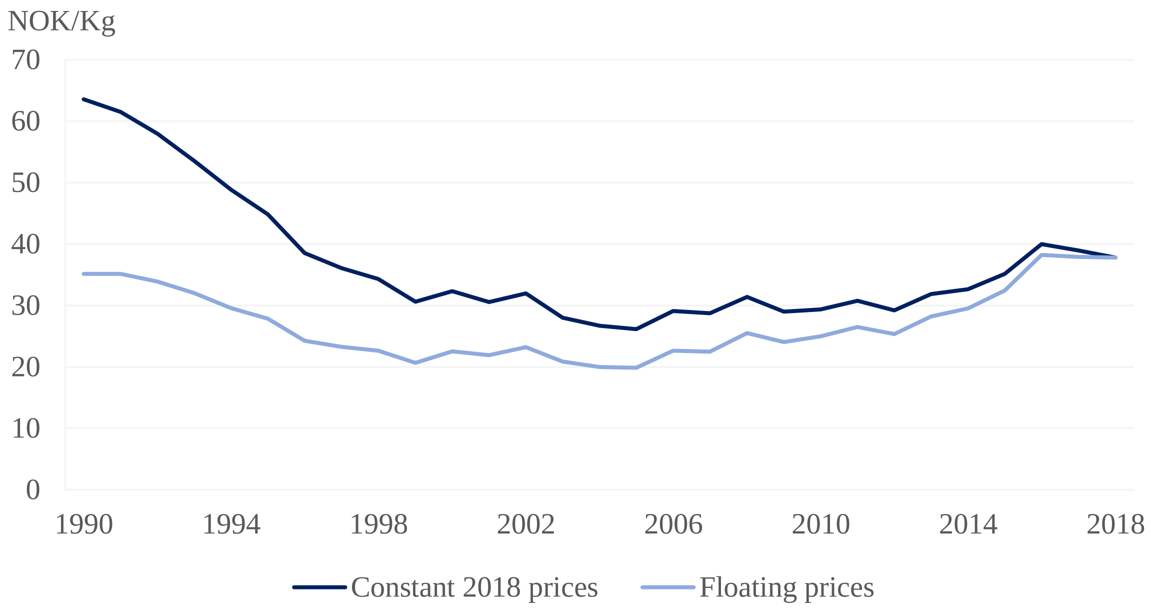
Figure 5 depicts the development in production costs per kilogram of gutted fish. The cost was falling significantly from the mid-1980s to 2005. The most important explanation for the declining costs is technological innovation combined with the liberalization of parts of the aquaculture act. A particularly important regulatory change was the repealing of the ownership restrictions in 1991,[8] and thus allowing for consolidation. As a result, farming firms started a process to exploit the suppressed potential for economies of scale (Bjørndal and Salvanes, 1995). However, owing to problems related to biology combined with higher prices for feed ingredients, costs have been increasing steadily since 2005.

Farmers typically report biological issues as part of other operating expenses in their financial statements. According to the profitability survey by the Directorate of Fisheries (2018a), other operating expenses account for approximately one-fourth of the total production cost per kilogram in 2017, compared to about nine percent in 2005. Although increased treatment activity and elevated mortality is an important cost driver, it is also essential to note that

[8] Until 1991, the authorities required local ownership of all farms. No farming firm could own more than one concession (see below) nor own a majority stake in another farming firm.

increased usage of specialized suppliers of services, maintenance, and an overall stricter regulatory framework also fuels the other operating costs. Like most forms of meat production, feed is the largest cost constituent and accounts for about half of the total production cost

Figure 5. Production cost per kilogram sold fish during 1998-2018

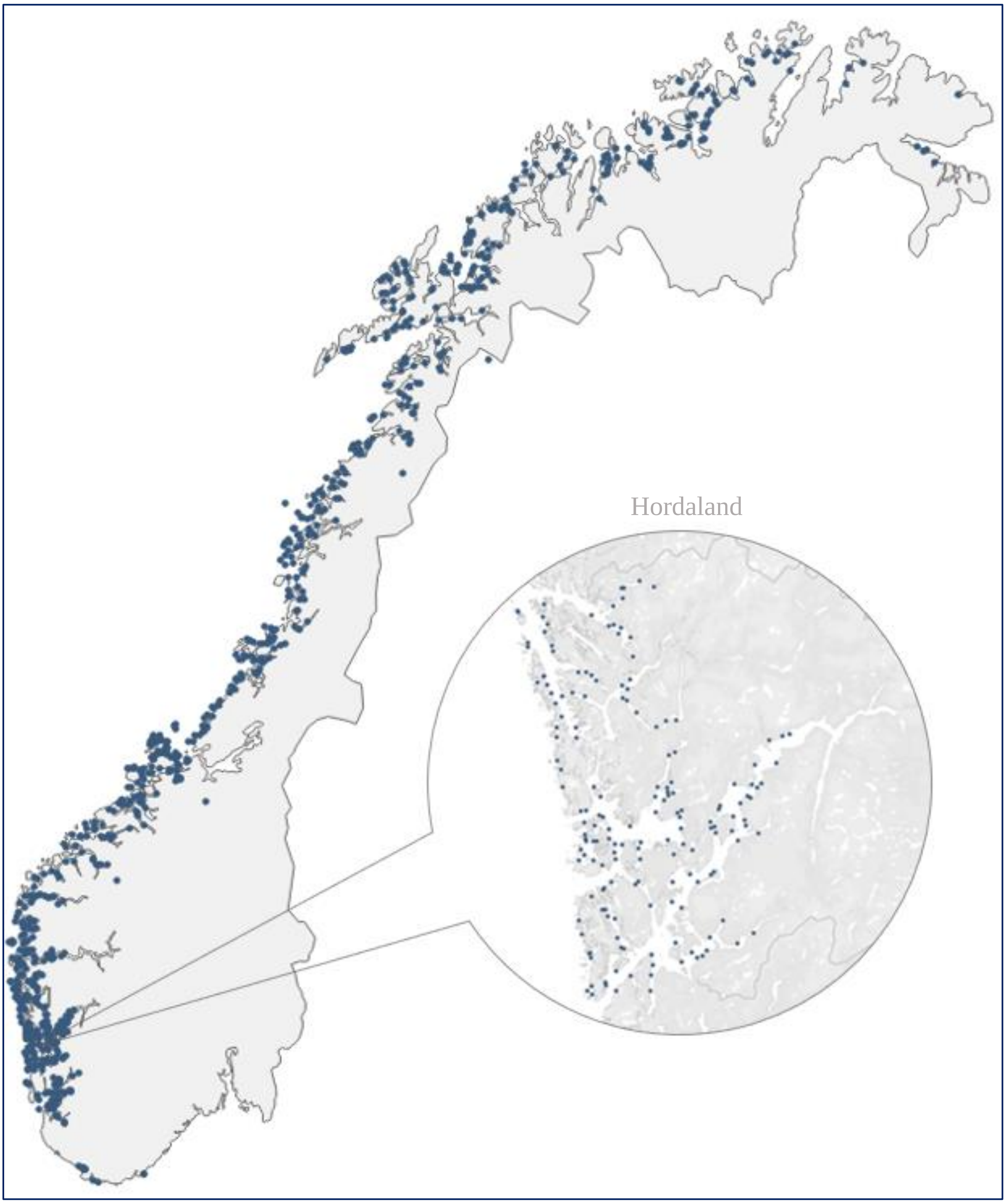


Notes: The figure shows production cost per kilogram of sold fish in GWE kilograms.
Source: DoF (2019b), SSB (2019)

For the last ten years, farmers have been operating an average of 810 active localities yearly, with an average production of 1,394 tonnes. Figure 6 shows all active localities during 2018, including an outtake of the Hordaland county to illustrate how farms lie in relation to each other. As seen in the figure, farms are located relatively close to one another, and the potential for transmission of diseases and parasites is easily imaginable.

This concludes the short introduction to both the global and the Norwegian production of salmon and rainbow trout. I now proceed to present the price development and market dynamics regarding exports.

Figure 6. Active localities during 2018



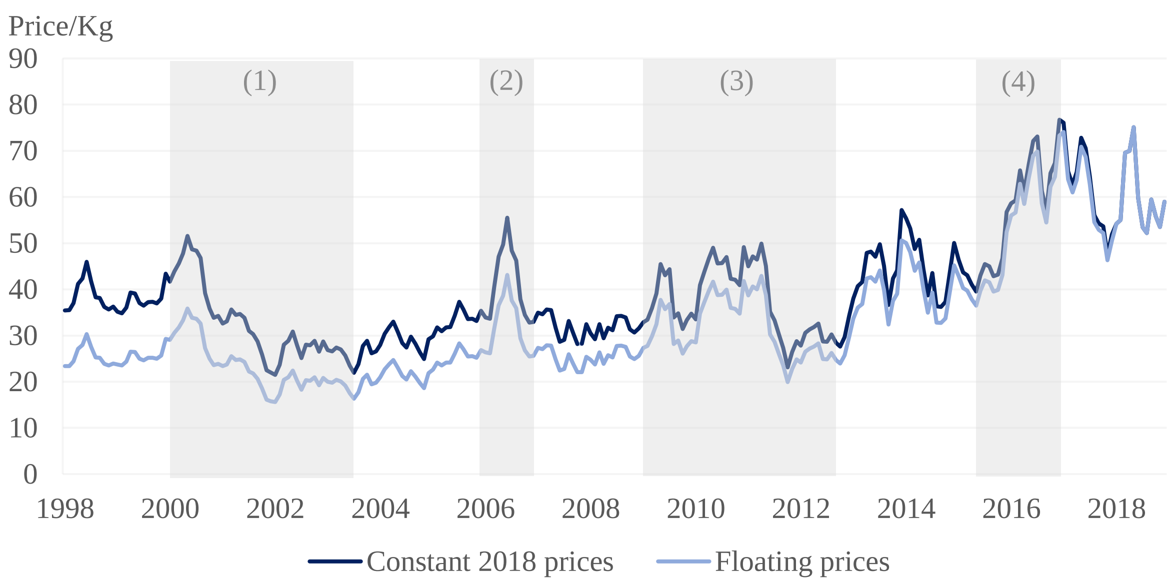
Notes: Shows all active production sites during 2018 (totaling 838 different sites).
Source: Mattilsynet (2019a)

2.3 Pricing and Markets

Farmers normally trade salmon and rainbow trout over the counter (OTC), either as spot transactions or by forward contracts. In addition to the trade of goods, Fish Pool serves as an international market place for buying and selling financial contracts with salmon as the underlying commodity. The purpose of this centralized market is to offer hedging and speculation possibilities for all stakeholders. Although industry players widely recognize the market, its size remains modest. In fact, only contracts equal to 67.5 thousand tonnes went through the system in 2017 (Fish Pool, 2018).

Because of the OTC structuring, agencies such as Nasdaq rely on collecting price information from a representative panel of Norwegian exporters. As mentioned, farmers label fish as either superior, ordinary, or production-grade. The price quotes normally represent superior, which accounts for about 90-95 percent of the total quantity produced in Norway. Moreover, exporters operate with a set of size groups (weight) and report prices accordingly. The most common size groups are 3-4, 4-5, and 5-6 gutted weight kilograms. Typically, larger fish are more expensive. Figure 7 depicts the monthly average spot price per gutted weight kilogram during 1998-2018.

Figure 7. Salmon price development during 1998-2018



Notes: Monthly average salmon spot price per GWE kilogram.
Source: NASDAQ (2019)

In 2018 the average price reached NOK 60 per kilogram and represented a 55 percent real increase from the average price of NOK 39 per kilogram in 1998. Despite the positive trend, the time series displays clear signs of significant volatility. Vertical bar (1) highlights a period with overproduction. The salmon market was very strong in the late 1990s, and farmers produced as much fish as possible (Skjeret et al., 2016). In fact, farmers produced 20 percent more fish in 1999 compared to 1998 (DoF, 2019b). Vertical bar (2) represents a demand increase resulting from an outbreak of bird flu, and salmon became a substitute for chicken and pushed prices up (Evans, 2006). Vertical bar (3) shows the effect of a supply shock from a disease outbreak in Chile (infectious salmon anemia) where prices soared because it opened the American market for Norwegian exporters (Alvial et al., 2012). In late 2011 one can see the result of a strong rebound of volumes from Chile as biological conditions normalized (also visible in table 1). Finally, vertical bar (4) shows yet another supply shock in Chile. This time from a severe algae attack combined with overall difficult biological conditions in Norway (Anderson et al., 2017, Hjeltnes et al., 2017).

As figure 7 illustrates, the commodity price is vulnerable to exogenous shocks. One important explanation is the long production cycle of approximately three years. Thus, short-term supply adjustments are practically impossible (within reasonable borders). Economists often say that the short-term supply curve is steep.

Most production nations rely on vast export markets with strong demand. Considering the general preference for fresh fish among customers, the main markets for most nations are often nearby, e.g., the most important markets for Norway is the EU, whereas the most important trade partner for Chile is the United States and South America (Mowi, 2019). One often refers to Asia as a shared market because it is far away from all major production nations. Thus, transportation costs (airfreight) are broadly similar. The United Kingdom is one exception from the exporting nations in the sense that most volumes are consumed within the UK (Mowi, 2019).

Given the relatively modest human population and substantial fish production, the domestic consumption of farmed fish in Norway only accounts for a marginal share of the total production. Specifically, Norwegians consume about five percent of the total production (Mowi, 2019). In 2018, the total export of salmon and rainbow trout from Norway reached 1.1 million tonnes, out of which 96 percent was salmon (SSB, 2019). Figure 8 shows all countries where Norwegian exports were one hundred tonnes or more in 2018.

The largest importers of Norwegian salmon and rainbow trout were Poland, France, and Denmark, with a total import of 14, 10, and 8 percent of the total quantity, respectively. A large processing industry explains the former and the latter, and both countries re-export most of the quantity as value-added products to, e.g., Germany and France. The most important reason farmers export fish for processing (secondary) is to avoid tariffs. Norway is not an EU member and faces high tariffs (up to 13 percent) on secondary processed fish because the EU wants to protect its processing industry (Kvalvik et al., 2016). For this reason, many of the largest Norwegian farming groups have their own processing facilities abroad, e.g., Mowi ASA's Morpol in Poland.

Geographical considerations suggest that the EU will remain the most important market for Norwegian seafood also in the years to come (Mowi, 2019). However, a weak NOK, strong global population growth, and overall improving living conditions world-wide opens new possibilities for further expansion into new markets.

Figure 8. Norway's most important export markets

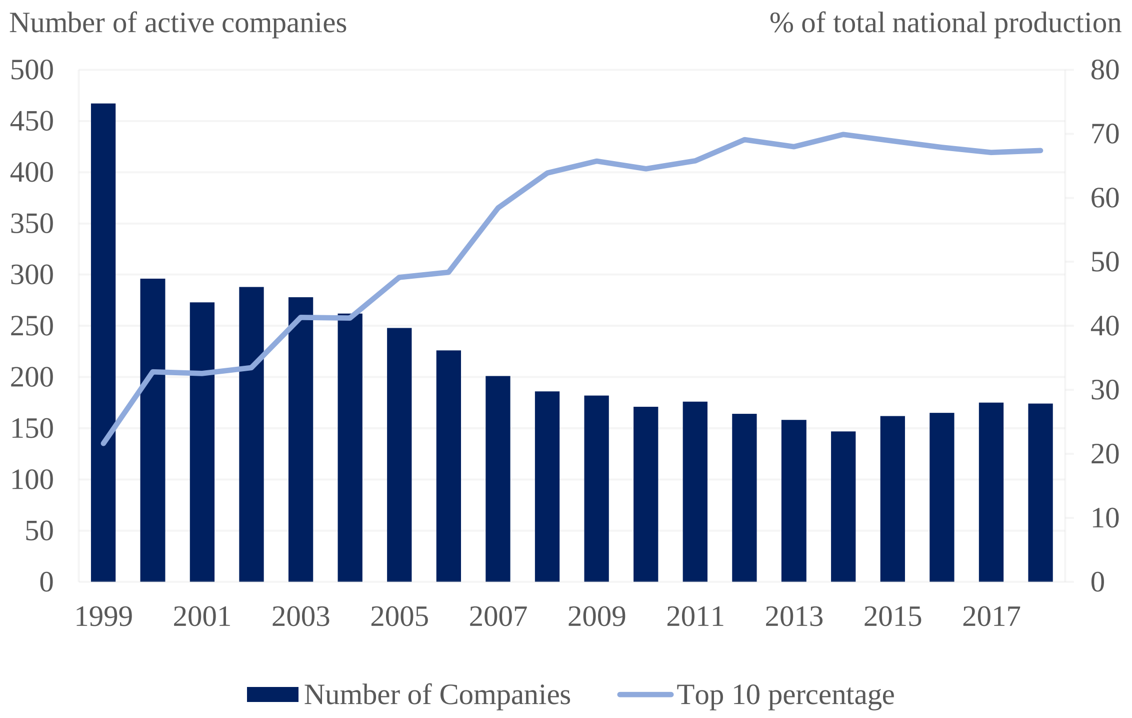
Notes: The map shows Norway's most important export markets in 2018, where important implies more than or equal to one hundred tonnes. Both the color darkness and size of the dots represent volume: the higher volume, the darker and larger dots. Source: SSB (2019)

Thus far, I have presented the production cycle, production metrics, pricing, and the markets. Now, I continue by introducing the most prominent salmon farming companies before I conclude the chapter by presenting important laws and regulations in addition to some of the current trends and development projects that could largely impact the industry going forward.

2.4 Industry Structure

In 2017, there were 174 active salmon and rainbow trout companies in Norway. However, many of the firms are subsidiaries of large farming groups. Thus, by accounting for legal ownership, the number decreases to about one hundred firms. Further, according to calculations by Mowi (2019), 22 companies control eighty percent of the total production in Norway. Figure 9 depicts the development of the industry structure from 1999 to 2018. As mentioned, the consolidation process started in the early 1990s and continues to this date (to some extent). The top ten players with respect to harvest volumes contributed 22 percent to the total volume in 1999 compared to 67-69 percent in the last seven years. The price fall in 2000 (see vertical bar (1) in figure 7) triggered a wave of bankruptcies and associated acquisitions. The substantial consolidation between 2005 and 2007 shows the effect of introducing new production regulations (see MAB below).

Figure 9. Top ten producers' share of total Norwegian supply during 1999-2018



Source: DoF (2019b)

Table 2 reports the top ten largest farming groups in 2018 based on harvest quantities. Mowi ASA is the largest company, with approximately 20 percent of the national supply. In addition, the company produces about 130 thousand tonnes abroad, e.g., in the UK, North America, and Chile. In aggregate, the company is the largest salmon producer in the world (with solid margins). As seen in table 2, six out of ten companies are public (ASA).[9] Implicitly, locally owned family businesses (AS) still control a significant share of the national production.

Table 2. Top ten largest companies based on harvest volumes in 2018

Company	Harvest in GWE tonnes	In % of Population
Mowi ASA	230 400	20.42
Salmar ASA	142 500	12.63
Lerøy Seafood ASA	137 800	12.22
Cermaq AS	57 400	5.09
Grieg Seafood ASA	46 100	4.09
Nova Sea AS	37 900	3.36
Nordlaks AS	36 100	3.20
Norway Royal Salmon ASA	36 000	3.19
Sinkaberg-Hansen AS	27 500	2.44
Alsaker Fjordbruk AS	26 000	2.30
Total	777 700	68.94

Notes: The population refers to the total production by Norwegian farmers (approximately 1 128 100 GWE tonnes in 2018). The abbreviations "AS" and "ASA" refers to private and public companies, respectively.
Source: Mowi (2019)

2.5 Laws and Regulations

The Norwegian aquaculture industry is subject to a rather complex legislative framework. This subchapter introduces the most important aspects of the framework with respect to the objective of this thesis. Specifically, I focus on licenses and production regulations. Also, I provide some insights into other relevant laws and regulations that are particularly important for the interpretation of the empirical results and the associated discussions, namely lice mitigation regulations.

[9] Mitsubishi owns all the shares of Cermaq AS and is therefore indirectly public. Further, Mowi ASA controls 43 percent of Nova Sea AS.

2.5.1 Licenses

The aquaculture act of Norway (2005) aims to facilitate profitability and ensure the competitiveness of the industry within the borders of sustainable development. The law outlines a policy in favor of coastal communities to prevent depopulation. A key managerial tool to promote the achievement of objectives is a licensing scheme. Chapter three of the aquaculture act dictates that a license is a prerequisite for all marine-based cultivation activities in Norway. A license, or concession, gives the holder a right to cultivate specific species, in a certain quantity, in a specific geographical area.

The general practice is that the authorities issue licenses continuously upon applications. However, this convention does not apply to sea-based salmon and rainbow trout concessions. Such permits exist in a fixed quantity and only allocated through (rare) public allocation rounds, in which the players compete either on a set of criteria or through auction to obtain additional permits. The reason salmon and rainbow trout receive different treatment compared to other species is largely its commercial potential that strongly encourages overexploitation.

Technically, the present licensing scheme functions by regulating the maximum allowed standing biomass (MAB). The MAB is 780 tonnes of fish (live weight) per license in all counties except Troms and Finnmark, where the limit is 945 tonnes because of slower growth in colder waters. A company that owns more than one concession in a specific area can add them together to define a company level MAB for this area. The holder must tie each concession to specific localities that have individual MAB constraints rooted in site-specific characteristics, e.g., water quality, currents, seabed purity, wildlife, distance to other localities, etc. In general, a farmer can associate one license with a total of four localities.[10] The median capacity of all Norwegian production sites is 3,120 tonnes, and the average production per license, measured in sold GWE tonnes, was 1,178 tonnes in 2017 (DoF, 2018a). One often refers to the company level MAB as a tool to limit production and the locality MAB as a method for protecting the environment. However, both levels work together to prevent the tragedy of the commons. The Directorate of Fisheries demands monthly biomass updates to enforce the legislation and have the power to impose penalties when appropriate.

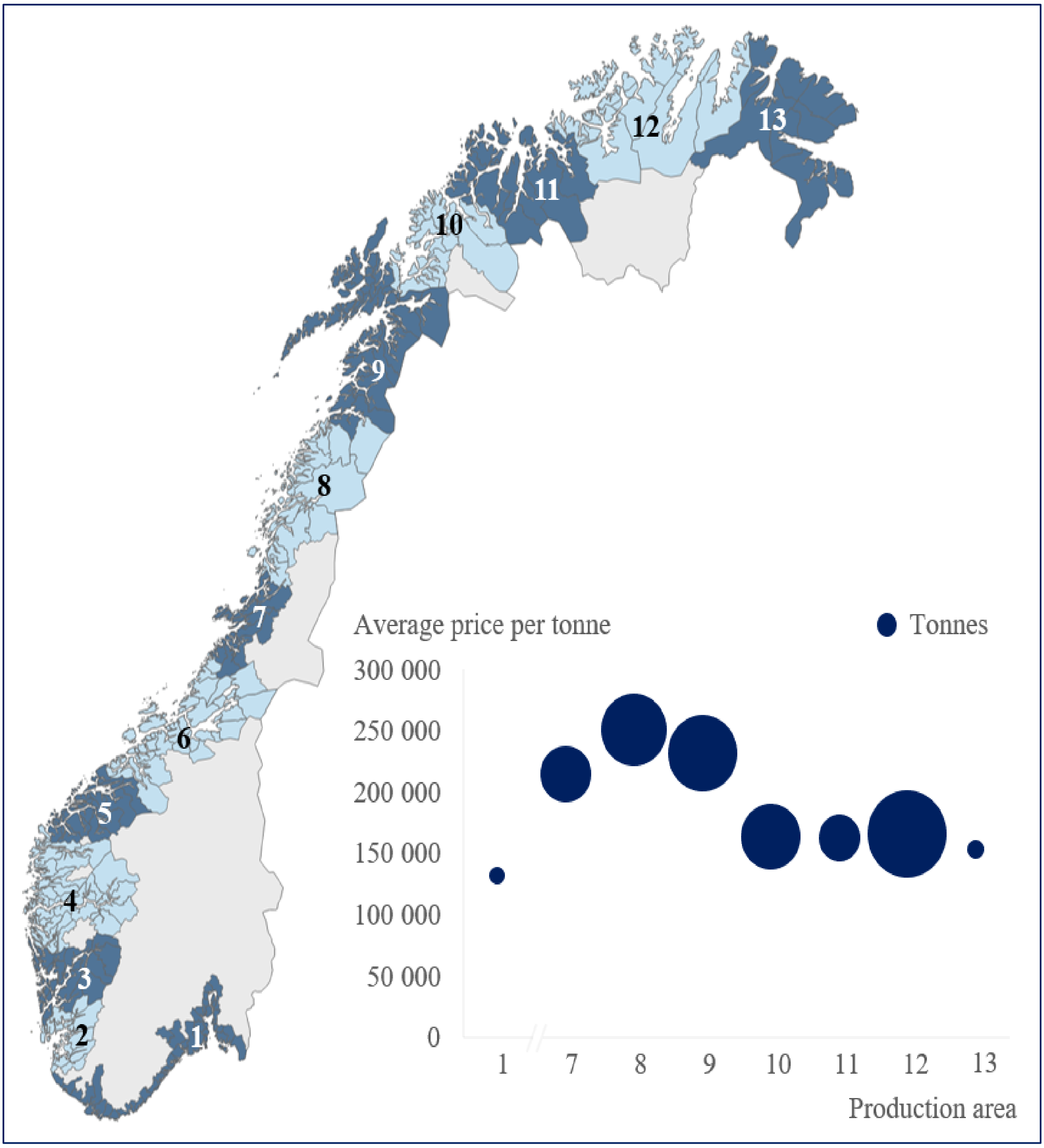
In addition to the traditional licenses described above, the authorities also issue licenses dedicated to educational purposes, broodfish, research, and development. The latter is a

[10] Alternatively, six sites if they all use the exact same licenses.

temporary scheme that issues project-specific concessions to facilitate significant innovation by reducing the overall investment risk of the undertaker. The purpose is to foster technology that can solve one or several of the environmental and area challenges the industry is currently facing. I return to some of the specific projects below.

In 2017, the Ministry of Trade, Industry, and Fisheries officially introduced new legislation that grants farmers with an opportunity to grow their MAB. The new policy outlined a system that divides the coastline into thirteen different production areas and assigns a status of either red, yellow, or green to each area depending on the overall lice situation. A green status implies a MAB increase, yellow is unchanged, and red triggers a MAB reduction. The magnitude of change in biomass is six percent. In late 2017, the authorities assigned a green status to eight areas (1,7,8,9,10,11,12, and 13), yellow to three (2,5, and 6), and red to two (3 and 4). Two percent of the green capacity was dedicated to expanding existing licenses, whereas four percent was sold at a public auction as new licenses. The weighted average cost per tonne at the auction reached NOK 195 thousand. Figure 10 depicts the distribution of production areas in addition to the realized auction prices per tonne in each of the green areas. Although two of the areas received a red status, the authorities will not enforce any reductions until the next status assessment scheduled in late-2019. In total, there were 1,041 concessions for commercial farming with a combined MAB of 909 thousand tonnes in Norway by the end of 2018.

Figure 10. Production areas and realized auction prices at the June 2018 auction



Notes: Shows the realized auction prices in the June 2018 auction. The x-axis shows the weighted average price per tonne, and the y-axis denotes each area. The bubble size represents the total number of tonnes purchased in each area.
Sources: DoF (2019b), SSB (2019)

2.5.2 Other Relevant Legislation

Adding to the aquaculture act mentioned above, the industry is also subject other laws and regulations, e.g., the food act (2003), the animal welfare act (2009), the water resource act (2000), the pollution act (1981), the harbor act (2009), the salmon and inland fisheries act (1992), the product control act (1976), regulations concerning daily operations of fish farms (2004), regulations on technical specifications of floating fish farms (2011), regulations concerning lice mitigation in fish farms (2012), etc. Of course, the industry is also subject to generalized Norwegian legislation, such as the working environment act (2005), the taxation act (1999), the national insurance act (1997), and so forth. A complete introduction to these laws and regulations is beyond the scope of this brief industry introduction. However, it is useful for the discussion in chapter six to have basic knowledge of the regulations concerning lice mitigation.

Lice are natural ectoparasites and feed off the mucus, skin, and blood of the host fish. Although modest levels of lice are not a major inconvenience to the host, higher levels lead to open wounds that, in turn, can cause anemia, difficulties with osmosis regulation, and lethal infections (Hjeltnes et al., 2019). Fish farms create ideal procreation conditions by having many potential hosts in a confined area. One major concern is how unnaturally high lice spawning activity in fish farms affects wild living salmon (Kristoffersen et al., 2017).

Although a salmon louse evolves through eight stages in its biological lifecycle (Heuch et al., 2000), the industry operates with three main classifications depending on the maturity of the louse: non-mobile (youngest), mobile, and female ovigerous (oldest). The regulations concerning lice mitigation in fish farms (2012) dictates that farmers must monitor and report the number of lice in each category weekly (small seasonal variations). The reported lice figure for each category represents an average of lice per fish based on a sample of between ten to twenty fish per pen. Although the authorities require lice numbers for each category, only the female ovigerous is subject to strict regulations in terms of maximum levels. For most of the year, the average female ovigerous per fish cannot exceed 0.5 without further actions from the farmer (e.g., treatments). [11] The Norwegian Food Safety Authority has the power to impose penalties if the farmers fail to adhere to the requirements.

[11] The limit is 0.2 six week per year: from week 16 to 21 in all counties south of Norland, and from week 21 to 26 in Nordland, Troms, and Finnmark.

This concludes the brief introduction to the most relevant legislation. The key takeaway from this subchapter is an understanding of the licensing scheme. Further, having a working understanding of the lice mitigation legislation, which is particularly important for the discussion of rent shifting effects in chapter 6. Now, I proceed to the last section in this introductory chapter, where I present some of the ongoing trends and developments that could largely impact the future of aquaculture.

2.6 Ongoing Trends and Developments

Fostered by a combination of high fish prices, increasing production costs, limited growth prospects of current production technology, and highly favorable development licenses, farmers are now developing several new systems that could greatly impact the future of salmon and rainbow trout cultivation. Figure 11 represents some of the innovations within core production technology.

Figure 11. Ongoing projects concerning core production methods

Sources: Mørenot AS (2018), MNH Produksjon AS (2018), Hauge Aqua AS (2018), Bulandet Miljøfisk AS (2018)

The first picture from the left represents ocean-based farming. The basic idea is to make new areas feasible for cultivation by constructing farms that can withstand the forces of nature at exposed locations. Advocates for this technology argue that it lowers the horizontal transmission potential in addition to having a lower impact on the ecosystem, e.g., by being located at a great distance to salmon rivers, cleaner water, deeper areas, etc. Salmar ASA is at the forefront of this technology and slaughtered their first-generation from the world’s first ocean farm (the one in the picture) in late 2018 with promising results. The company expresses confidence in its vision of ocean rigs as an essential part of the future of aquaculture (Salmar ASA, 2018).

The second picture from the left represents semi-closed farming methods, where the idea is to establish a permanent barrier in the upper levels of the sea where the lice normally exist (Hevrøy et al., 2003). Midt-Norsk Havbruk AS is at the forefront of this technology and currently develops a semi-closed pen “Aquatraz” made of steel. A cheaper alternative that builds on existing plastic pens is fabric lice skirts, which have the same basic functioning as the new pens. However, modern semi-closed pens incorporate a lot more than just lice protection. First, it pumps water from great depths to renew the water in the closed section, which ensures oxygen-rich water with optimal temperature. Second, the installation facilitates easy cleaning to improve hygiene. Third, it has automatic systems for gathering fish in case of treatments, deliveries, or sorting, which significantly lowers the stress levels of the fish. Finally, it eases and safes the daily operations for the workforce.

The third picture from the left represents closed-pen farming methods, where farmers keep the fish in a fully controlled environment. Most ongoing projects involve a continuous renewal of water inside the pen from great depths by using the same pumping technology as the “Aquatraz” above. Further, the technology collects any waste products, which allows for alternative usage of highly applicable raw materials, for example, as fertilizer or biofuel. Besides, it also reduces the biological pressure on the ecosystem. As a result, the technology is safer on the environment and is less likely to suffer from negative externalities. However, a big challenge for this technology is to ensure adequate animal welfare and water quality. Further, the usage of pumps to continuously renew water implies high energy costs and a significant vulnerability towards any power-outs.

Finally, the right-hand side picture represents land-based farming methods. Most systems use a recycling system for its water, often referred to as RAS (Recirculating Aquaculture Systems), which implies that the plant can operate without having an endless supply of high-quality water. That said, even the most advanced RAS solutions require a certain water replacement regularly. The biggest advantage of this technology is that farmers can produce fish closer to, or in, the end markets and save transportation costs. Although land-based solutions have many advocates, the established sea-based farmers tend to focus their resources and knowledge of fish biology towards improving sea-based production forms, e.g., through releasing larger smolt (see below) rather than investing in land-based grow-out facilities. The biggest drawback of land-based production methods is high energy costs and substantial capital expenditures.

As the industry has become increasingly more advanced, there has been a strong demand for goods and services. For this reason, the aquaculture industry consists of a lot more than just farming companies. In fact, the aquaculture service and supplier industry grow at even higher rates. Typically, farmers rely on purchasing everything from roe to equipment and wellboat services from external companies. Figure 12 represents some of the most notable ongoing trends in the service and supplier industry that could affect the future of farming and help solve existing challenges.

Figure 12. Ongoing trends and projects in the service and supplier industry

Sources: Aquagen AS (2019a), Lerøy Seafood ASA (2018), Napier AS (2019), Unknown (available at datafloq.com/read/artificial-intelligence-future-of-programming/5124).

The first picture from the left represents advancements in genetics and biology. Farmers show an increasing willingness to pay for new products that claim to prevent lice or ensure resistance against various diseases. There are currently several interesting vaccines in development in addition to considerable QTL effort to breed lice-repelling fish.

The second picture from the left represents post-smolt production, which is a semi land-based farming method. Farmers are investing substantially in growing larger smolt on land. The basic idea is to limit the exposure time at the locality. By keeping the fish on land up to weights of 500 grams to one kilogram, one effectively reduces the time at sea by approximately half. Thus, lowering the biological risk significantly. However, there are still issues that need solving, e.g., challenges with early sexual maturity.

The third picture from the left represents processing vessels, which replaces wellboats in the harvest stage of the production cycle. Processing vessels have “stun and bleed” systems that kill the fish at the time of loading and stores the fish in chilling wells. Consequently, the fish does not depend on oxygen-rich water nor room to swim during transport, which implies that the vessel can carry more fish per cubic meter of well capacity and use completely enclosed wells even at long-duration transit. There is also one fully functioning slaughtering vessel in operation, “Norwegian Gannet”. This vessel conducts the entire primary processing stage onboard (except grading and packaging) while transiting to a specialized facility in Denmark. Although the technology is highly efficient, it receives considerable political resistance in Norway because it has the potential to threaten jobs at processing facilities along the coast.

Finally, the last picture from the left represents the usage of data. Farmers collect considerable amounts of data from their operations but do not utilize its full potential in decision making. To further develop systems to ease planning and improve predictability is of high value in distributing limited resources. Many companies are currently developing systems for automatic feeding, biomass control, lice prediction, etc.

2.7 Summary

The Norwegian aquaculture industry has evolved greatly from its inception in the 1950s. Today, Norway is the world’s second largest seafood exporter in terms of value. High profitability, combined with challenging biological conditions and overall strict regulations, has resulted in considerable ongoing innovation and development that could largely impact the industry going forward. The most important takeaways from this introductory chapter is an overall understanding of the aquaculture industry, together with a more detailed understanding of the intricate relationship between present production technology and the ecosystem, which define the very premises of the current regulatory system.

3. Theory and Related Literature

In this chapter, I review and summarize the large body of literature on resource rent with an emphasis on empirical work. Despite the increased importance of aquaculture in the world economy (FAO, 2018), issues related to resource rent in the industry has yet to receive significant attention from economists. For this reason, most of the research presented below covers other resource industries, particularly the somewhat relatable fishing industry. The purpose of this review is to establish expectations for my empirical analysis in addition to uncovering potential gaps in the existing literature. In this chapter, I start by introducing the theoretical concept of resource rent, followed by a review of the existing literature. Next, I discuss the implications of the findings from the literature review for my empirical analysis of resource rent in the Norwegian aquaculture industry in addition to highlighting potential gaps in the existing literature.

3.1 The Theoretical Concept of Resource Rent

In a competitive market without any form of entry restrictions, one would expect a frim with positive profits to encourage entry to that industry. Conversely, one expects negative profits to trigger altered behavior or exit from the same industry (Varian, 1978). Thus, a competitive market induces players, both existing and aspiring, to continuously innovate to produce the underlying good or service at the lowest possible cost. Following this reasoning, the optimal level of production in a competitive market is the level where the marginal production costs equal the market price, i.e., it is optimal to produce (and sell) one extra (marginal) unit if the income from selling the marginal unit exceeds the production costs of that unit. Economists often refer to the intersection between marginal costs and demand (revenue) as market equilibrium, in which the long-term variable profit is equal to zero for all firms.[12]

Economic profit, by definition, represents the difference between revenue and the total costs, including opportunity costs of capital, of supplying a good or service to the market. It follows from this definition that a competitive firm earns economic profits if the marginal cost exceeds the average cost in equilibrium. Such positive differences cannot hold for competitive markets in the long run due to the attraction of new entrants. However, the positive economic profit can

[12] Under the assumption of homogeneous firms.

persist in the long run if there are any constraints to the supply side, e.g., scarcity of resources, or political motives (Varian, 1978).

The supply side in the Norwegian aquaculture industry is subject to constraints due to the scarcity of the underlying resources. Current managerial principles of the nation's natural resources aim to ensure sustainable exploitation that does not impair the long-run productivity of the resources (Becker et al., 1997, Ministry of Trade Industry and Fisheries, 2015). As mentioned, licenses are the most important tool to ensure sustainable development, and given the limited growth in the number of issued licenses during the last seven-eight years, it is reasonable to assume that concessions are a significant bottleneck for further production growth. For this reason, the only way farmers can increase output is to use more intensive farming methods, e.g., high growth feed, size separation techniques, postponing treatments, etc., which enables them to produce more within the same maximum allowed biomass constraint. Such methods imply higher marginal costs and consequentially increasing average costs. Thus, marginal costs are higher than average costs in the equilibrium, and the industry should experience positive economic profits from scarce resources.

Sustained economic profit is a privilege to the holders of licenses since we know from above that such profits cannot exist in the long run in a competitive market. As a result, the commercial value of access to the resources must be equal to the difference between profits in the regulated market minus profits in a non-regulated market. A simple production function adapted from Varian (1978) clarifies the concept:

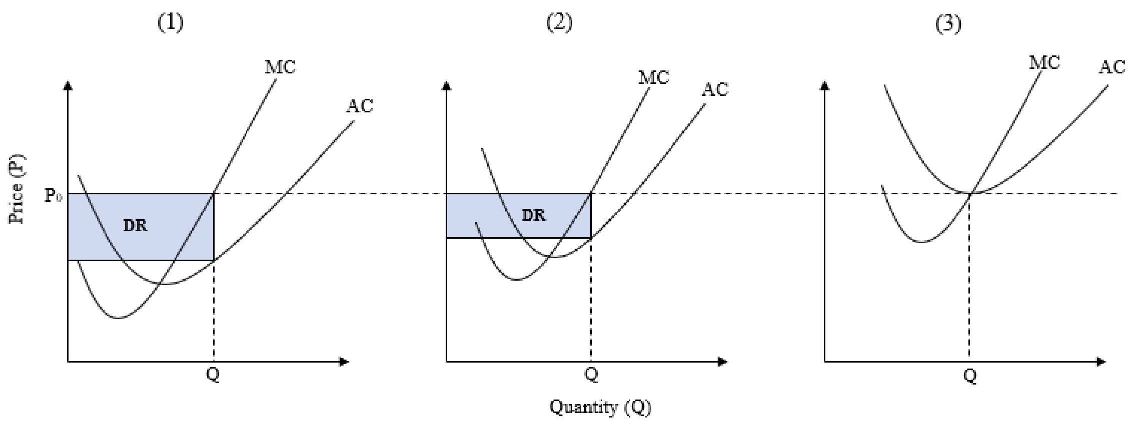
$$Profit = p^* y^* - c(y^*) \tag{1}$$

where $p^*$is the price of output given the optimal quantity y^*, and $c(y^*)$ is the total cost of producing y^*. Drawing on the principles from above, the value of a resource must be equal to the positive profits. Thus, the owner of a resource can lend it to any rational producer for a sum equal to $p^* y^* - c(y^*)$, which in principle, is equivalent to a rent payment of a fixed factor. This value is what economists term "resource rent", namely the economic profit from exploiting natural resources. The profits in the industry are due to the rent on scare resources, and thus the long-run operational profits will still be zero in equilibrium (Varian, 1978).

The concept stems from the seminal works of Adam Smith (1776) and David Ricardo (1817), both of which wanted to distinguish between the efficiency gains of the producer (e.g., skills, technology, etc.) and the benefits from the natural resource itself. The literature separates between several different kinds of rent, for example, differential rent, scarcity rent, and quasi rent. Economists often refer to the former as Ricardian rent, after the late David Ricardo. According to Ricardo (1817), there are situations where site-specific characteristics are more favorable in one area compared to another, and thus the same amount of capital and labor will yield different outputs depending on the production site. In aquaculture, such differences might be due to, e.g., water purity/quality, currents, temperature, bathymetry, weather exposure, horizontal transmission pressure, etc.

Figure 13 depicts a scenario with three different fish farms (1), (2), and (3). A key assumption of the figure is that all farms are price takers; that is, neither farm is large enough to affect market prices. Further, all farms are operating optimally. The blue shaded area(s) represents the differential rent (DR). AC is the average cost, and MC is the marginal cost of production.

Figure 13. Differential rent (Ricardian)

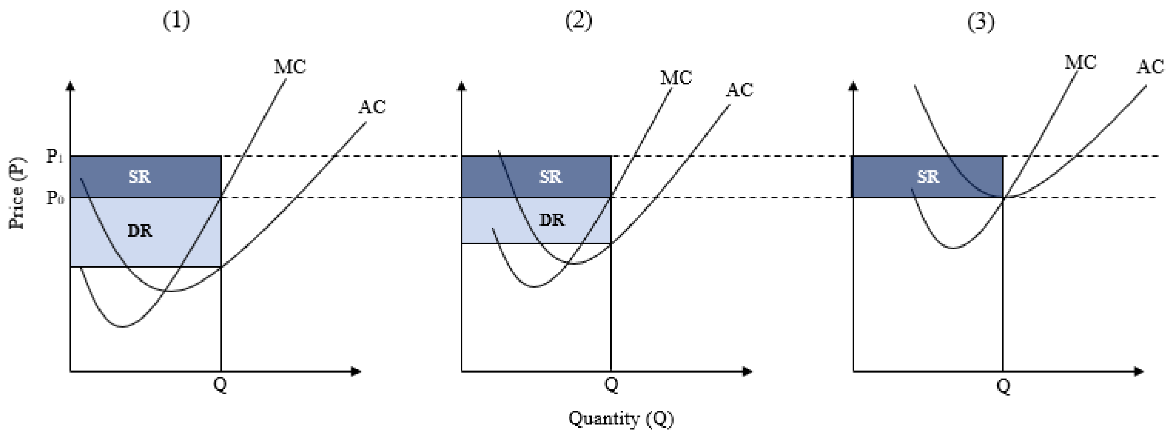


Source: Luchsinger and Müller (2003)

The figure clearly illustrates that Farm (1) benefits from higher quality resources by having lower costs of exploitation, since the blue shaded area is larger than the corresponding area for Farm (2). Farm (3), on the other hand, suffers from poor production conditions with the result of relatively high operational costs and no differential rent. The key takeaway from Figure 13 is that parts of the rent stems from the quality of the resource itself and varies across production sites. Being unable to adjust quantities upwards in the event of increased demand facilitates a situation where demand can exceed the supply and prices increase. The rent that stems from such scarcity is by economists referred to as scarcity rent.

Scarcity rent arises when demand exceeds supply and is only possible in the long run if supply is subject to constraints. Figure 14 depicts the formation of scarcity rent (SR).

Figure 14. Scarcity Rent



Source: Rothman (2000), Luchsinger and Müller (2003), Author

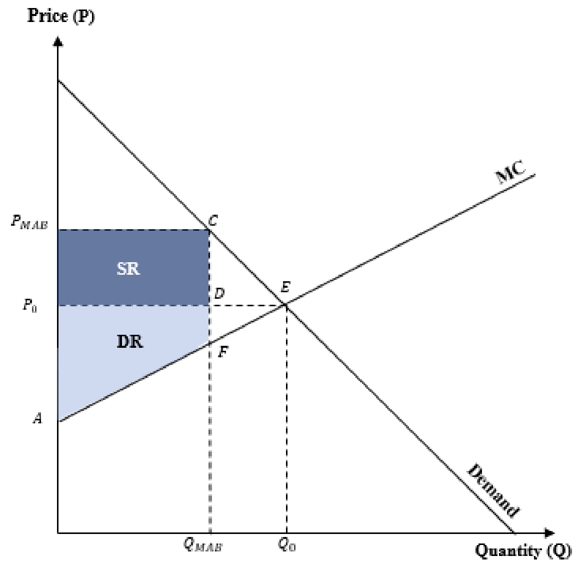
In Figure 14, the demand shifts upwards and fosters a price increase from p_0 to p_1. The legally enforced scarcity of the resources (MTB constraints) prevents farmers from adjusting Q to establish a new equilibrium where $p_1 = MC$. As a result, SR is positive and corresponds to the dark-blue shaded area. An interesting feature of the SR is that it can generate abnormal profits in marginal firms, as seen by Farm (3). Thus, even the less favorable localities are now generating substantial rent. Because of the central role of regulations in forming scarcity, one may refer to SR in this situation as "regulatory rent".

Both DR and SR originate from the resource itself and therefore make up the resource rent. However, it is essential to note that managerial efforts (e.g., investments, firm structure, etc.) and technology do affect the magnitude of the rent generated (Bjørndal et al., 2013). Further, considering the relative size of Norwegian production, it is reasonable to assume a degree of market power with associated potential for monopoly rent. Therefore, the amount of rent that a resource generates depends upon the collective behavior of both the exploiters and the resource owners (Boadway and Flatters, 1993). For this reason, one typically assumes that exploiters seek to maximize the net present value of economic profits and thus aim to maximize the resource rent by their decisions, e.g., all investments are value-adding, etc. The last type of rent I cover in this theoretical introduction is quasi rent.

Quasi rent (QR), also known as intra-marginal rent, stems from differences among producers (farmers) due to strategic actions, e.g., new technology, economies of scale, procedures, skills of the workforce, branding, etc. In contrast to the resource rent, competitors tend to mitigate the quasi rent in the long run by adopting similar strategies (Luchsinger and Müller, 2003). Consequentially, the quasi rent has a low expected value in a mature industry. There is, however, no clear indication that the aquaculture industry has reached maturity. In fact, the evidence indicates the opposite. There are still large differences between how firms operate, and the industry has yet to solve core issues related to, e.g., biology. As a result, several major ongoing projects could impact the industry greatly in the future. Thus, one should expect some degree of quasi rent in the Norwegian fish farming industry.

Figure 15 conceptualizes the resource rent in the Norwegian aquaculture industry. The output has a theoretical maximum in Q_{MAB} which is lower than the free-competition equilibrium of Q_0, which corresponds to an upward shift in prices from P_0 to P_{MAB}. As a result, the scarce resources generate resource rent equal to DR+SR minus potential QR. The methodology in chapter four outlines an empirical strategy to estimate the absolute value of the shaded area.

Figure 15. Conceptualizing resource rent in the Norwegian aquaculture industry



Source: Author

Thus far, I have elaborated on the concept of resource rent. I now proceed to review parts of the existing literature on the subject, with emphasis on the empirical work. That is, the focus is on papers that have quantified the rent in various resource industries. The primary motivation for estimating resource rent is twofold. First, rent represents the value of a nation's natural resources and thus should be part of national wealth calculations together with real capital, human capital, and financial capital (Lindholt, 2000). Second, and perhaps the most prominent motivation, to assess who benefits from the natural resources and consider potential rent capture schemes to redistribute potentially skewed benefits.

Rent capture is when authorities, on behalf of the public (the resource owners), aims to collect parts of the rent through various schemes, e.g., royalties, taxes, auctions, etc. to benefit the public and not the exploiters exclusively (Rothman, 2000). Rent capture and the effectiveness of various capturing strategies are topics for a substantial body of literature, see for example Garnaut and Ross (1975), Copithorne et al. (1985), Heaps and Helliwell (1985), Amundsen et al. (1992), Grafton (1993), Osmundsen (1995) and Zhang (1997). However, rent capture is beyond the scope of this thesis, and I focus on the literature that documents and quantifies the resource rent in various industries. I limit my review to studies in Europe with the most attention towards the Nordics. I start by reviewing the existing work within fisheries economics, followed by a few examples from hydropower and petroleum. I conclude the review by assessing the very limited body of literature on rent in aquaculture.

3.2 Literature Review

Gordon (1954) initiated the modern literature on resource rent in fisheries in his seminal paper "The economic theory of a common property resource: the fishery". In this paper, he addresses the lack of fundamental economic understanding among biologists by developing a simple bioeconomic model. One of his most important contributions was to disclose the difference between uncontrolled and controlled (by governmental management) exploitation of natural resources and its long-term implications. He shows that under an open access fishery, the best harvesting grounds (represented by Farm (1) and (2) in Figure 13) attracts more fishers, and the average productivity equalizes across all ground in the long run. Scott (1955) extends Gordon's discussion by considering the difference between short and long-term decision making by exploiters. Both studies stress the benefit and importance of sole ownership (entry restrictions) and that such arrangements yield the highest resource value. In fact, both authors argue that the resource rent is zero in open-access fisheries due to excess capacity and depleted stocks.

Two decades later, Copes (1972) published a paper in which he argues that, despite the resource rent being zero in open-access fisheries, there can still be intra-marginal rent (quasi rent) in heterogenous fishing fleets. Several studies address the issue of separating intra-marginal rent from resource rent, see for example, Coglan and Pascoe (1999), Bjørndal et al. (2013), and

Jensen et al. (2019). Bjørndal et al. (2013) confirm empirically that the expected quasi rent in a mature and well-managed resource industry is very low. [13]

Resource rent is a common measure of profitability and efficiency in the fisheries literature. Numerous studies assess the issue of rent dissipation under inefficient management policies, i.e., they study the potential rent under optimal management, see for example, Dupont (1989), Weninger (1998), Homans and Wilen (2005), and Bjørndal et al. (2013). All studies find a significant dissipation due to sub-optimal (excess) capacity and illustrate the substantial gains from eliminating excess capacity and adopting the most efficient technology.

Following the same objective, Steinshamn (2005) develops a linear programming model and apply this to the Norwegian fisheries. He uses data from the Directorate of Fisheries and finds that the current realized resource rent is one-tenth of its potential. According to Steinshamn, the optimal industry structure requires a reduction of input variables (fishers and vessels) by roughly fifty percent. Greaker et al. (2017) run the same model on newer data, and the conclusions are very similar to Steinshamn (2005) despite the decade that past between the studies. Although both papers confirm the presence of resource rent, rent realization is modest due to the excess capacity problem. Following an akin approach, Paulrud (2006) and Andersen et al. (2010) identify the same trends in Sweden and Denmark, respectively.

Hannesson (2005) develops a radically different approach compared to the aforementioned papers. He investigates the resource rent by utilizing data on realized market prices of traded quotas in Norway. Thus, the methodology is directly dependent on the assumption of rational investors, and that market values truly represents the net present value of rents. Although the model is novel, it produces similar results to Steinshamn (2005). However, Hannesson points to several limitations to his approach; for example, some investors (license owners) may assign quotas to an existing vessel and therefore do not account for fixed costs in auctions. Naturally, such cases may increase the willingness to pay for a license. On a general note, access to adequate data is a complicating factor for using this approach.

Nielsen et al. (2012) investigate the development or resource rent in several fisheries in the Nordic countries. The authors develop a three-staged bioeconomic model and apply data from Norway, Sweden, Iceland, Denmark, and the Faroes Islands. The model, including all

[13] The study finds that the intra-marginal rent accounts for two percent of the total rent (98 percent is resource rent) in the North Sea Herring Fishery.

assumptions, are similar across all nations to ensure comparability. The authors conclude in the same manner as most other research in the field; there is resource rent in fisheries, but there is an enormous potential through reducing capacity. In addition to proposing cuts in the existing capacity, the authors also suggest that a low rent may be due to other managerial concerns, such as coastal population, etc. which comes at the cost of less efficient resource utilization.

Gunnlaugsson and Agnarsson (2019) compare two different models for measuring resource rent in the setting of the Icelandic fishery. One of the models, “the WACC method”, builds on the same principles of economic profits from the finance literature as the model I develop in chapter 4. However, a key difference is that Gunnlaugsson and Agnarsson (2019) uses total assets, which also includes financial assets, as opposed to the invested capital (see chapter 4). The second approach is based on the return on the capital differential between the firms in fisheries and the average Icelandic company (estimated without fisheries). This framework implicitly assumes that the residual after correcting for “normal returns” (which the average company generates) is the resource rent. Both methods report somewhat similar results, although the WACC method is slightly higher on average. The authors prove that the Icelandic fishery is highly profitable and generates substantial resource rent.

Thus far, I have presented selected parts of literature focusing on resource rent in the fisheries. Now, I turn the attention towards other natural resource industries. An example from the Norwegian hydropower market is the study by Amundsen and Tjøtta (1993). Hydropower has several similarities to aquaculture in the sense that both depend on the common property resource of water and designated areas. A significant bottleneck in this industry is access to feasible production areas, which together with production regulations (concessions) gives rise to considerable rent. The authors estimate an annual rent in the range of eight to fifteen NOK billion, depending on assumptions (e.g., the cost of capital).

A similar study is the Banfi et al. (2005) study of rent in the Swiss hydropower industry. Based on a sample of sixty different production sites, the authors estimate the potential resource rent in case of a fundamental restructuring of the regulatory framework for hydropower firms in the nation. The current (in 2005) regulations are based on a fixed-fee scheme irrespective of the operational performance of each firm. The authors conclude that the annual resource rent is close to EUR 650 million, which shows potential for additional rent capture above the realized EUR 330 million collected from the in-place fixed-fee system.

Lindholt (2000) estimates the resource rent in a wide variety of resource industries in his effort to calculate the national wealth of Norway during 1930-1995. He applies data from the national accounts and evaluates the rent in forestry, fishing, hydropower, agriculture, mining, and petroleum. There are large differences between the various industries, and not surprisingly, petroleum had the largest rent with a peak of approximately NOK 80 billion in 1985 (in 1995 NOK).[14] His time series analysis clearly illustrates the importance of commodity prices on rent generation, for example, a supply shock triggered a fall in the petroleum rent of 75 percent from 1985 to 1986 (Lindholt, 2000, The World Bank, 2015).

Following a similar approach, Greaker et al. (2005) conduct an empirical analysis of the national wealth of Norway between 1985 to 2004. The authors present a somewhat more detailed picture of rent generation in various industries, including a separate account for aquaculture. The overall conclusions are the same as in Lindholt (2000), and the generation of rent is well-documented.

The above studies show that resource industries have the potential to generate rent, and most studies emphasize the importance of strict regulations to preserve and maximize the resource value. In many cases, other managerial objectives, or simply poor management, e.g., absence of quotas or other forms of production regulations, suppresses the overall wealth generation (resource rent). As described in chapter two, the Norwegian aquaculture industry is highly regulated, and Norway is a considerable player on a global scale with the associated potential for market power. Thus, one should expect to disclose rent in the aquaculture industry.

As mentioned, Greaker et al. (2005) investigate the development of the national wealth of Norway during 1985-2004, including aquaculture. To the best of my knowledge, this is the first empirical study to assess the rent in aquaculture explicitly. The authors conclude that the aquaculture industry generated positive rent in eleven out of twenty years with a peak in 2000 of approximately NOK 4.5 billion. [15]

Flaaten and Pham (2019) analyze the resource rent in 2016 exclusively based on a sample of 68 percent of the total farming population in Norway. They segregate the resource rent into scarcity rent and Ricardian rent (differential rent). The aggregate resource rent estimate totals NOK 15.774 billion, out of which 6.596 and 9.117 billion is SR and DR, respectively.

[14] Approximately 125.4 billion measured in 2017 NOK

[15] Approximately 6.3 billion measured in 2017 NOK.

Converting the estimates to a per kilogram gutted weight equivalent basis yields NOK/GWEkg 18.57, 7.76, and 10.81, respectively.[16] Moreover, Flaaten and Pham also utilize the Faustmann framework to estimate the value of a license to NOK 138 million. The authors do not make any attempt to isolate quasi-rents in their analysis.

Furthermore, unpublished results by professor Mads Greaker suggests a resource rent of NOK 27 billion in 2016 (Berglihn and Ytreberg, 2018). He derives his estimate from the national accounts following the same method as in Lindholt (2000), Greaker et al. (2005), Greaker et al. (2017), with a cost of capital of four percent. Adjusting the results of Flaaten and Pham (2019) to both accounting for the whole population and a cost of capital of four percent yields a resource rent of approximately NOK 24 billion in 2016. Although the estimates result from vastly different methodologies, they are clearly in the same ballpark, which adds validity to both estimates. Further, professor Mads Greaker together with Lars Lindholt has recently conducted a study of resource rents in both aquaculture and hydropower in Norway during 1984-2018. However, only the results from hydropower are public at the time of writing this thesis (NOU2019:16).

To conclude, the above review shows that well-managed resource industries have the potential to generate resource rent. Most papers stress the importance of strict policies and production regulations to ensure positive rent. In fact, most studies encourage redistribution of rights from less efficient producers to more efficient producers to maximize rent. The two studies focusing on the Norwegian aquaculture industry provides evidence of positive rent, especially the Flaaten and Pham (2019) study. For this reason, I should expect to find positive rent in 2016.

Furthermore, it appears that few empirical studies to date have analyzed explicitly the rent shifting effects that potentially occur in fragmented value chains, i.e., most existing literature relies on the assumption of either complete vertical integration by the license holder or perfectly competitive markets in the non-licensed parts of the value chain. Situations, where these assumptions do not hold empirically, may produce biased results. For this reason, I now proceed to develop my preferred empirical approach for estimating the resource rent with an aim to capture potential rent shifting effects as well.

[16] The sample contains 956,153,580 kilograms of WFE (whole fish equivalents/round weight), of which 869,563,784 and 86,589,796 kilograms are salmon and rainbow trout, respectively. The conversion ratio from WFE to GWE is 0.889 for salmon and 0.881 for rainbow trout. As a result, the weight I use for the conversion is 849,327,814 GWE-kilograms.

4. Methodology

This chapter describes my empirical approach for estimating resource rent in the Norwegian aquaculture industry. As mentioned, resource rent is simply the economic profit from exploiting natural resources. For this reason, I utilize and adopt a standard definition of economic profit from the economic literature, such as in Berk and DeMarzo (2017). Drawing on this basic definition, I build a model for estimating the resource rent generated by license holders (farmers). Furthermore, I extend my model to also consider rent capture in other parts of the value chain, i.e., the model relaxes the common assumption in the existing empirical literature that the license holder captures the entire rent, and allows for rent shifting within the value chain.

This chapter is structured as follows. First, I introduce the basic model for estimating economic profit, including a full introduction to all its variables and how I derive them empirically. Second, I explain how I extend the basic model to fit the purpose of this thesis, including how to capture rent shifting effects. Finally, I express the concluding model for the total resource rent in the Norwegian aquaculture industry.

4.1 Economic Profit – A Standard Model

As mentioned, economic profit represents the difference between revenue and the total costs, including the opportunity cost of capital, of supplying a good or service to the market. Formally, one can express economic profit EP in period t as:

$$EP_t = EBIT_t - \overline{IC_t} * WACC_t \tag{2}$$

where $EBIT_t$ represents operational earnings before interest and taxes, $\overline{IC_t}$ is the average invested capital during period t, and $WACC_t$ is the required rate of return (before tax) on invested capital.

The first term of the right-hand side ($EBIT_t$) is the accounting-based difference between revenue and costs, whereas the second term reflects the opportunity cost of capital. Contrary to Gunnlaugsson and Agnarsson (2019), I focus on operational assets only rather than total assets. That is, I measure the performance of core operations exclusively to avoid noise from financial assets. The main argument for making this distinction is that the value of exploiting natural resources is, by definition, operational. As a result, the output from estimating eq. (2) measures the direct benefit from exploiting the natural resource in period t.

With the basis for my empirical model in place, I now proceed to elaborate on how I compute each variable in eq. (2). I start by explaining EBIT and IC and conclude with the required rate of return (WACC).

4.2 Operational Income and Invested Capital

Estimating EBIT and IC of a given firm starts with the reported financial statements, which in its traditional form, consists of five parts and discloses key insights to the financial position of the entity. Part one is a profit and loss statement (revenue and costs), part two is a balance sheet (assets, equity, and debt), part three is a cash-flow statement, part four is a statement of changes in equity, and part five contains notes. The latter contributes with detailed explanations of single accounts (Petersen et al., 2017). As reported, financial statements do not distinguish between operating and non-operating assets/profits and sources of financing (Koller et al., 2015). Consequentially, one must reorganize the reported statements to obtain the necessary variables for eq. (2).

Reorganizing financial statements starts by classifying all accounts, either as operating or non-operating. Determining which activities to deem operating or not, relies on the business model and individual characteristics of the firm in question (Petersen et al., 2017). As mentioned, EBIT represents earnings before interest and taxes. Hence, obtaining the EBIT figure starts by reorganizing the profit and loss statement to disclose earnings and costs directly related to core operations (operational income). This implies only to consider, e.g., fish-related income for a fish farming firm. The concluding figure from removing all non-operational accounts equals the operational income (EBIT) and is compatible with eq. (2).

With the EBIT variable in place, the next step is to reorganize the balance sheet to obtain an estimate of the IC. IC is the invested capital and represents the net operating assets, which are necessary to generate EBIT, i.e., the amount invested in operations that requires and generates return. Consistency is key during this process. If one includes income (operational) from an asset in the profit and loss statement, one must also include the asset itself (operational) in the balance sheet. Although most accounting items are easily categorizable, some require special consideration. To a large extent, I lean on recommendations set forward by Petersen et al.

(2017) during this part of the reorganization process. I present the most important considerations below.

The first consideration regards non-recurring items, e.g., disposal of non-current assets, impairment losses, etc. Such items tend to represent an adaptation to new market conditions, restructuring, or consolidation. In a rapidly changing industry, this trend is likely to continue, and thus non-recurring items are mostly operational. A second consideration regards investments in associates and related cash flows. In most cases, such accounts are a direct consequence of a strategic vertical integration scheme. On this basis, I mostly include such arrangements in both the operational EBIT and the IC. The third consideration is with respect to cash. I separate cash into excess and operating according to Koller et al. (2015) with a cut-off value of two percent of total sales in line with Opler et al. (1999). A fourth consideration regards non-controlling interests, which I treat as equity rather than debt. The main argument is the required rate of return on minority interest, which one assumes is significantly higher than the cost of debt. Arguably, the rent is even higher than for equity due to a potential illiquidity premium (Pratt, 2009). The fifth consideration regards pension obligations, which I treat as a financing activity. The main argument is that pension obligations are interest-bearing and thus receive a non-operational cash flow. A sixth consideration relates to deferred taxes. This accounting item does not earn interests and is therefore not a financial item. For this reason, I classify deferred taxes (both assets and liabilities) as operating. For a detailed discussion of deferred taxes, see for example, Petersen et al. (2017). The last special consideration is my treatment of dividends. I regard dividends as equity and, therefore part of the invested capital for the given year.

When the above process is complete, one adds together equity and net-interest bearing debt (interest-bearing assets minus interest-bearing debt) to obtain the IC figure. The average invested capital ($\overline{IC_t}$) is simply the average during period t ($(IC_t + IC_{t-1})/2$).

After completing the above procedure for each company in the data set, I form segments of similar companies (see below) and combine all reorganized financial statements within each segment to form segment-based financial records. I perform all the remaining computations using the segment-based accounts.

Thus far, I have introduced $EBIT_t$ and $\overline{IC_t}$, including how I estimate the two. Now, I turn to explain the required rate of return ($WACC$) and related parameters.

4.3 The Required Rate of Return

The required rate of return on capital is an expression for the compensation a rational capital supplier requires to encounter risk. In this context, risk refers to a situation where future company cash flows may deviate negatively from the initial expectations at the time of supplying capital. In principle, the cost is merely a function of risk and thus often referred to as the opportunity cost of capital, which compares to the value a capital supplier can earn from alternative projects with an identical risk profile. Another term for the same cost is “discount rate”. This term stems from a common valuation technique called net present value estimation, where one discounts future cash flows with the appropriate rate to reflect risk. I use all the above terms interchangeably throughout the remainder of this thesis.

In general, companies can raise funds in two ways: equity or debt. Investors supply the former, and creditors supply the latter. An important distinction between them is that debt has a prior claim on company earnings and therefore carries less risk compared to equity. Given that most firms have both sources of financing in their respective capital structures, one must derive a total cost of capital for the entity. To accommodate the differences, I calculate a weighted average of the capital costs with relative exposure to each source of financing as weights. This approach is commonly known as the weighted average cost of capital method (WACC) and is widely recognized in both finance and industry (European Research Group, 2007).

Formally, one can express $WACC$ after tax in period t as:

$$WACC_{after\ tax,t} = \left[\frac{E_t}{E_t + D_t}\right] * r_{E,t} + \left[\frac{D_t}{E_t + D_t}\right] * r_{D,t} * (1 - \tau_t) \qquad (3)$$

where E_t is equity, D_t is net interest-bearing debt, $r_{E,t}$ is the cost of equity, $r_{D,t}$ is the cost of debt, and τ_t is the corporate tax rate in Norway. The specification of eq. (3) is on an after-tax basis but eq. (2) requires a before-tax figure. For this reason, I transform the output from eq. (3) by adjusting for tax effects in eq. (4).

$$WACC_t = \frac{WACC_{after\ tax,t}}{(1 - \tau_t)} \qquad (4)$$

where $WACC_t$ is the before-tax opportunity cost of capital. It follows from the specification of eq. (4) that I assume equal tax rates on income for both companies and private investors. This simplifying assumption is helpful in avoiding problems of insufficient information regarding taxes paid by all stakeholders. Moreover, existing research argues that the effect of accounting for the different tax rates yields neglectable impacts on the overall capital cost (Johnsen, 2017). The output from eq. (4) represents the opportunity cost of capital and adequately accounts for the appropriate level of risk involved in underlying operations of the company in question. I now continue by explaining how to estimate the parameters in eq. (3) and (4) based on available information in period t.

4.3.1 Cost of Equity

As mentioned, investors provide equity financing, and therefore the cost of equity reflects the cost of capital from an investor's perspective. A suitable framework for estimating the appropriate cost is the capital asset pricing model (CAPM). Despite criticisms that it is too simplistic (Black et al., 1972), it has been the favored method among practitioners for decades (Graham and Harvey, 2001). The basic idea of the model is that investors require compensation for risk. The risk in this model is twofold with a systematic and non-systematic (firm-specific) component. One assumes that all investors hold a diversified portfolio of assets (e.g., several stocks mixed with bonds), and thus cancel out the non-systematic constituent. For this reason, the cost of equity should not include any diversifiable risk (Koller et al., 2015). The degree of risk compensation a given investor can demand equals the difference between the expected return of the market and a risk-free alternative (market risk premium).

A common expression of CAPM follows from eq. (5):

$$r_{E,t} = r_{f,t} + R_{Mkt,t} * \beta_{E,t} \tag{5}$$

where $r_{f,t}$ is the risk-free rate, $R_{Mkt,t}$ is the market risk premium (unit price of risk), and $\beta_{E,t}$ is the equity beta and represents a coefficient for systematic risk (units of risk). For an in-depth explanation of the model, see for example, Fama and French (2004) or Berk and DeMarzo (2017).

I use ten-year Norwegian treasury bonds (yearly average) as a proxy for the risk-free rate (Norges Bank, 2019) and adopt estimates of the market risk premium from existing research (NBIM, 2016). I calculate the equity beta based on listed seafood companies on the Oslo Stock Exchange, OSLSFX, with OSEBX as the benchmark index. The beta is simply the variation coefficient from simple statistics expressed as:

$$\beta_{E,t} = \frac{Corr(\tilde{R}_{E,t}, \tilde{R}_{Mkt,t}) * \sigma_{\tilde{R}_{E,t}}}{\sigma_{\tilde{R}_{M,t}}} \tag{6}$$

where $\tilde{R}_{E,t}$ is the equity return, $\tilde{R}_{Mkt,t}$ is the benchmark return (OSEBX), and σ is the standard deviation.

I compute all estimates on a five-year rolling basis and the output from eq. (6) represents the equity beta of each listed company in the industry. These estimates, however, reflect the capital structure of each firm individually and is not directly applicable to other firms (non-listed) in the same industry. For this reason, I perform a de-levering procedure to disclose the systematic risk associated with the operational assets:

$$\beta_{A,t} = \frac{\beta_{E,t}}{(1 + \frac{D_t}{E_t})} \tag{7}$$

Eq. (7) adjusts for potential differences across capital structures and reports the asset beta of aquaculture operations (primarily) in Norway. I then apply the asset beta to the segment-based cumulative statements to account for segment-specific capital structures. It is important to note that asset betas originate from market values, whereas the segment-based calculations use book values. This difference could introduce a bias to the final estimate, in the sense that it underestimates the beta.

Thus far, I have presented the WACC concept and how I arrive at the cost of equity. Now I turn to the last component of WACC, the cost of debt.

4.3.2 Cost of Debt

As mentioned, debt has a priority claim on earnings and is, therefore, less risky compared to equity. I estimate the cost of debt simply by adding a segment-based debt premium to the risk-free rate. The debt premium in this thesis corresponds to credit default spreads in the US bond market, i.e., the debt premium is the difference between a risky and a non-risky traded bond. To derive the appropriate premium for each segment, I assign a synthetic rating of default risk to each segment based on four financial ratios: interest coverage ratio, current ratio, equity share, and ROIC. The common denominator of all ratios is their relation to both short and long-term ability to pay occurring expenses. For a detailed explanation of each variable, see for example, Petersen et al. (2017). The concluding synthetic ratio is based on a scale from triple-

A to D, where triple-A is extremely strong and D is default. Then I translate the letter rating to a quantitative ratio by consulting Liu et al. (2018).

Formally, one can express the cost of debt in period t as:

$$r_{D,t} = r_{f,t} + d_{Mkt\ t} \quad (8)$$

where $d_{Mkt\ t}$ is the debt premium from the quantitative synthetic rating.

This concludes my presentation of the basic model and how I estimate each variable. Now, I proceed to draw on the basic model to formalize my empirical approach for estimating resource rent in this industry.

4.4 Resource Rent

For this thesis, I split the resource rent term into farming rent and rent shifting. The former is the resource rent, as it traditionally follows from empirical research. That is, it assumes that the license holder captures the full rent. The rent shifting component relaxes the assumption and aims to correct the cost term of the farming firms to account for possible rent in other parts of the value chain. I start by addressing the farming rent followed by rent shifting on a per kilogram gutted weight basis (GWEkg), before I conclude this chapter by combining both to arrive at an expression for the total resource rent in the industry.

4.4.1 Farming Rent

This section describes my empirical approach to identify resource rent in the farming segment. The model draws directly on eq. (2) and extends to measure economic profit per kilogram of sold fish. Empirically, I analyze the resource rent based on a representative sample of the farming population. For this reason, I need generalizable results which scales to provide an estimate for the entire farming population in Norway.

A formal expression of the model in period t is:

$$rf_t = \frac{EP_{f,t}}{W_t^S} \quad (9)$$

where rf_t represents resource rent in the farming segment per GWEkg, $EP_{f,t}$ is the economic profit in the farming segment, and W_t^S denotes the weight of the sold fish in the sample measured in GWEkg.

Estimating eq. (9) on a representative sample produces scalable output, which is applicable for adjustments according to national volumes of sold fish. With that in place, I now proceed to extend the model to include rent shifting effects.

4.4.2 Rent Shifting

As detected during the literature review, the existing research on the topic of resource rent assumes that the license holder captures the entire rent. However, most firms rely on suppliers of goods and services, and thus the accounts of the license holder (farming firm) may not contain the actual cost of carrying the resource to the market, i.e., the difference between revenue and total costs in eq. (2) may not be true. As a result, I extend my model to include rent from all parts of the value chain by carefully analyzing potential economic profits contained in the reported production costs of the farming entities. My strategy to adjust costs implies calculating an appropriate multiplier, which accounts for and corrects for economic profit contained in the reported production costs. Technically, the multipliers represent a correction for the average economic profit percentage in each cost account of the farming firm, e.g., economic profit in the smolt costs, economic profit in the other operating costs, etc. I derive the economic profit by analyzing the financial accounts of a representative sample of supplier firms. Table 3 shows the working principle of my approach:

Table 3. The working principle of the rent shifting estimation

(A)		Production cost	As reported
(B)	-	Production cost adjusted	= (A)*multiplier
(C)	=	Rent shifting	= (A) – (B)

As seen in table 3, the rent shifting is simply the production cost differential between (A) and (B) and represents the economic profit contained in a given production cost, which the farming entity (license holder) does not capture. That is, the cost for the farming firm is higher than the suppliers' production cost (including normal profits) of the given good or service, which in turn introduces a negative bias to the resource rent calculated from the financial accounts of the farming firm (EBIT is too low).

In general, the established practice for reporting production costs in fish farming revolves around eight different cost groups: smolt, feed, assurance, personnel, depreciation, net financial costs, process (including transportation), and other operating costs, see for example DoF (2017) or Iversen et al. (2018). In line with the strategy presented above, I aim to calculate an economic profit percentage within each of these groups and thus rely on collecting a representative sample of firms within each group. Based on an in-depth analysis of the financial statements of farming firms in combination with a thorough review of the entire value chain, I identify segments of similar companies that make up the various cost groups, see table 4 (for a description of each segment, see chapter 5).

Table 4. Segmented cost groups

Cost groups as reported	Segmented cost groups
Smolt	Smolt
	Roe
	Smolt
Feed	Feed
	Feed Producers
	Feed Carriers
Assurance	Assurance
Personnel	Personnel
Depreciation	Depreciation
	Equipment (long-term)
	Shipyards
	Non-sea-based equipment
Other operating costs	Other operating costs
	Cleaner fish
	Fish health
	Equipment (short-term)
	Service vessels
	Wellboats
	Non-sea-based equipment (short-term)
	Other services
Net financial costs	Net financing costs
Process and transportation	Process and transportation
	Transporting (x % of wellboat cost)
	Processing
	Packaging

The segmentation relies on a set of assumptions. First, I assume that 50 percent of equipment and 75 percent of non-sea-based equipment are intended for long-term usage. The numbers follow from a careful assessment of product portfolios of each company, in combination with statements from large farming firms that they expense smaller outlays and expenditures as they incur (Mowi, 2018). However, I acknowledge that other analysts may arrive at slightly different estimates, but the distinction is important to adjust depreciation (firms capitalize long-term assets). Second, I assume a gradually larger share of wellboat activity over time is treatment-related and thus belong to other operating costs rather than transportation. I set the initial share of wellboat activity in other operating costs to 10 percent (in 2010), which I gradually increase to reach 50 percent in 2017. The numbers originate from a review of treatment statistics, and most importantly, communication with several wellboat firms and vessel employees. If I do not adjust for the changed behavior of wellboat firms, I risk exaggerating the EP percentage in the process and transportation group.

That said, I now proceed to express my strategy formally. I continue to utilize eq. (2), but now I calculate the total EP in each cost group in percent of the total revenue in the same group to obtain an EP percentage for cost adjustment (multiplier). The multiplier for cost group j in period t follows from eq. (10):

$$\pi_{j,t} = 1 - \left[\frac{\sum EP_{ij,t}}{\sum R_{ij,t}}\right] \tag{10}$$

where $R_{ij,t}$ is the revenue in segment i in group j in period t.

The above procedure applies to all cost groups except depreciation, which requires a minor adjustment. Depreciation is a method for allocating cost to an asset over the expected useful lifetime of that asset. Therefore, depreciation in period t is not only a result of new assets in period t but also all capitalized assets that are not fully depreciated before period t. It follows from the time notation in eq. (2), that I shall only adjust for changes in depreciation during period t. For this reason, I calculate the economic profit percentage in the depreciation cost group, but I only adjust the changes during period t. I suggest the following extension to eq. (10) for computing the multiplier for the depreciation cost group:

$$\pi_{dep,t} = 1 - \left[\frac{dep_t - dep_{t-1}}{dep_t} * \frac{\sum EP_{i\ dep,t}}{\sum R_{i\ dep,t}}\right] \tag{11}$$

where $\pi_{dep,t}$ is the multiplier for the depreciation cost group, and dep_t is the total depreciation cost in period t from the financial statements of the farming firms, and the last term in the RHS bracket measures the economic profit percentage in the depreciation cost group. A weakness of eq. (11) is its dependence on three critical assumptions. First, capital expenditures are the only driver of changes in depreciation, which implicitly assumes that farmers only sell outdated assets. Second, all investments have the same average premium. Third, all investments follow a linear depreciation schedule, which implies that the asset cost is equally distributed over the lifetime of the asset. All assumptions are strict and may not hold empirically, which introduces some uncertainty to the estimates. However, in the absence of significant outliers, the impact of depreciation costs on the total rent shifting effects have a low expected value. Hence, there is only a potential for modest noise inflicted upon the total resource rent estimate from these assumptions.

With that in place, I apply the appropriate multiplier from eqs. (10) or (11) to the reported cost in the financial statements of the farming entity to obtain the adjusted cost in line with eq. (12):

$$C_{j,t}^{A} = C_{j,t}^{R} * \pi_{j,t} \tag{12}$$

where $C_{j,t}^{A}$ and $C_{j,t}^{R}$ is the adjusted and reported costs in cost group j in period t, respectively. The estimate from eq. (12) represents the actual cost of goods and services of exploiting the resource, i.e., the adjusted cost is net of any rent shifting effects.

Based on this reasoning, one can formally express the total rent shifting effects in the sample in period t as:

$$rs_t = \sum \left[\frac{\left(C_{j,t}^{R} - C_{j,t}^{A}\right)}{W_t^S} \right] \tag{13}$$

where rs_t is the total rent shifting effects in the sample per GWEkg in period t. Figure 16. illustrates the estimation of rent shifting effects on a constructed example.

Thus far, I have presented both the farming rent and rent shifting effects. Finally, I combine the two in one expression for the total resource rent below.

Figure 16. Example – Rent shifting estimation

A data set contains a representative sample of all parts of the value chain. The farming firms in the sample report a combined feeding cost and other operating cost of 500 and 200, respectively. Applying eq. (10) to the feeding cost (feed carriers and producers) yields a multiplier of 0.9. Doing the same for the other operating cost (Wellboats, Service Vessels, Fish Health, and so forth) gives a multiplier of 0.8. That is, the rent shifting is 10% in the feed cost group and 20% in the other operating cost group. The farming companies produce (and sell) a combined quantity of 1000 GWE kilograms of fish. Following the above methodology results in a total rent shifting of 0.09 per GWE kilograms in the sample, of which 0.05 and 0.04 stem from feed and other operating costs, respectively.

Feeding costs		
	Reported feed costs	500
-	Adjusted feed costs (500*0.9)	450
=	Rent shifting total	50

Other operating costs		
	Reported other operating costs	200
-	Adjusted other operating costs (200*0.8)	160
=	Rent shifting total	40

Rent shifting in the sample		
	Rent shifting feed	50
+	Rent shifting other operating	40
/	Quantity of sold fish in sample	1 000
=	Rent shifting in the sample per GWEkg	0.09

4.4.3 Total Resource Rent

The resource rent in the Norwegian aquaculture industry in period t follows from the combined expression of eq. (9) and (13), which one can define as:

$$rr_t = fr_t + rs_t \tag{14}$$

where rr_t is the industry-wide resource rent per GWEkg. Under the assumption of a representative data set, the output from eq. (14) is scalable to account for national volumes to obtain the total resource rent:

$$RR_t = rr_t * W_t^P \tag{15}$$

where W_t^P is the total weight of sold fish by the Norwegian farming population in GWEkg.

The results from estimating eq. (15) is my aggregate estimate for the resource rent in the Norwegian aquaculture industry in period t. With the empirical strategy in place, I now continue to describe the data set to which I apply the above procedure.

5. Data

Having established the methodology for the empirical analysis of this study, I now introduce the data set that will allow me to estimate the resource rent in the Norwegian aquaculture industry. The data set contains 745 legal entities and combines non-public material provided by the Directorate of Fisheries (DoF) with a vast collection of publicly available information. The composition of the data set is representative of the entire industry. Consequently, it encompasses firms from all parts of the value chain, for example, roe, smolt, farming, and processing.

This chapter proceeds as follows. First, I describe the process of gathering data, including the construction of the final data set. Then I present my data, including simple descriptive statistics based on revenues. Last, I address the overall representativeness of the sample.

5.1 Data Gathering

To ensure the reliability of my estimates, I need to construct a data set which truly represents the actual population. Gathering an appropriate sample is a comprehensive task and requires a variety of methods. The final data set consists of two main components: farming and non-farming companies. I will now describe the sources and the construction process for each component sequentially.

My primary source of information on farming firms is the annual profitability survey from the DoF. Attendance is mandatory for all farming companies in Norway. However, several entities are not present every year. There are several reasons why a firm is missing in a given year, such as inactivity, incomplete (or missing) submission forms, and intricate business structures[17]. The survey contains 63 variables for each observation and provides insight into production characteristics that are unobtainable from the financial statements and annual reports for most responders, for example, a detailed breakdown of quantities, inventories, costs, and sales.

I combine the survey data with complete financial statements on all firms in the DoF data set obtained from the Brønnøysund Register Centre (BRC).

[17] Some farming groups report difficulties in isolating the farming business from other activities.

The second component of my data set contains information on non-farming companies. To the best of my knowledge, there are no official data sets on suppliers of goods and services within the aquaculture industry. Hence, identifying relevant players is considerably more complex in this case compared to the farming case.

I initiate my scout for non-farming firms by searching through standardized categories, or codes, used for industrial classification in Norway (SSB, 2008). Each category consists of a short description of its content and a unique code. Then I employ the relevant codes to the Central Coordinating Register for Legal Entities in Norway to recognize individual firms within each category. Also, I collect and utilize historical exhibitor lists from exhibitions, such as Aqua-Nor, Nor-Fishing, and LofotFishing. The former is the world's largest technology exhibition for the seafood industry according to the organizer (Aqua Nor, 2019). Further, I supplement with companies identified through complete supplier lists from two large farming groups. And finally, I rely on extensive web browsing. Appendix 1 reports all industrial codes represented in the final data set.

Following the identification process, I consult BRC for complete financial statements for each firm. I exclude companies if they meet one or more of the following criteria: it has less than two years of reported revenue, it has less than one employee, and it has zero capitalized assets. Furthermore, I also exclude companies where aquaculture is not an important business area with respect to total sales, where I base the assessment of importance on information from annual reports, communication with the firms in question, and web browsing. A guiding principle is that aquaculture should account for at least half of total sales in all firms. Lastly, I only include first-order supplier firms, that is, firms that provide goods or services directly to the farming firm. The final sample holds 616 non-farming entities with a total of 4032 fiscal years over the sample period, 2010-2017.

The concluding step of the data set construction phase is to study and understand the operations of each company to cluster units with similar core activities. This is the mentioned segmentation, which is essential for the methodology, as described in chapter four.

5.2 Segmentation

Table 5 depicts the fifteen different segments that I define and use in my analysis. As mentioned, I chose segments based on an in-depth analysis of the financial statements of farming firms in combination with a thorough review of the entire value chain. The observant reader will notice that I do not include sales and marketing, neither as a segment nor in the data set altogether. I exclude this final step of the value chain because of insufficient information regarding quantities sold in each company. Moreover, sales entities tend to have low IC, and ROIC may thus not be a suitable measure of historical performance.

By omitting the final stage of the value chain, I risk the possibility of miscalculating the RR. However, according to my calculations and several publications by EY (2016, 2017, 2018), the sales segment has an overall low-margin tendency, which by definition, restricts the possibility of significant rent generation. Based on the preceding arguments, I assume arm's length pricing[18] of all trades between farming and sales affiliates, i.e., the farming division is de facto capturing most of the rent from fish sales. Considering this assumption, I expect the farming segment to hold most of the rent from sales.

[18] The arm's length principle states that the price paid between related parties must be the same as if the parties were unrelated.

Table 5. Segments and descriptions

Segment	Description
Farming	Firms are producing the fish commodity (license holders).
Roe	Providers of genetic material (salmon and trout eggs).
Smolt	Spawning and smoltification firms.
Wellboats	Providers of wellboat services, such as transportation and treatment of livestock.
Service Vessels	Firms typically operate heavy-duty catamarans intended for treatments, mooring work, fish delivery, inspections, and so forth. The segment also includes diving, net-cleaning, and treatment* firms.
Feed Producers	Providers of fish feed pellets. The segment does not include ingredient companies, e.g., fishmeal and fish oil.
Feed Carriers	Providers of feed pellet transportation at sea.
Cleaner Fish	Firms engaged in farming or catching cleaner fish.
Equipment	Providers of equipment for the sea-based production phase.
Processing	The segment includes both primary (slaughter and whole fish) and secondary processing (VAP) firms.
Packaging	Providers of plastic, paper, labeling solutions, and Styrofoam.
Fish Health	Firms related to all aspects of fish health, e.g., laboratories and veterinarians. The segment also includes medical firms providing various remedies, for example, vaccines, disinfectants, and specialized medical feed.
Non-Sea-Based (NSB) Equipment	Providers of equipment intended for all onshore stages of the production cycle, e.g., slaughtering and packaging machines, conveyor belts, and smolt tanks.
Shipyards	Firms engaged in the production of wellboats, service vessels, feed transporters, and personnel transportation vessels.
Other Services	All other firms that do not fit into the above categories but are essential for the value chain. Ranging from electricians to certification companies.

*This is companies owning and operating large ships, or barges, exclusively intended for treatments (e.g., Thermolicer, Hydrolicer, Skamik, and Optilicer).

Thus far, I have described the data gathering, data set construction, and the segmentation process. In the following section, I present key characteristics and the summarized statistics of the data set.

5.3 Data set Characteristics

The final data set is unbalanced, which implies that the number of fiscal years is less than the full period (2010-2017) for some units. Mergers, acquisitions, and restructuring are the most prominent explanations for the imbalance. Table 6 reports simple summary statistics based on revenues during 2010-2017.

Table 6. Summary statistics of annual revenues by segment in NOK thousands.

	(1) Units	(2) N	(3) Average	(4) Median	(5) Aggregate (2010-17)
Farming	129	720	362 565	161 673	255 899 325
Roe	12	78	80 356	34 276	6 267 741
Smolt	90	633	26 949	16 068	17 058 811
Wellboats	29	182	75 395	19 899	13 721 859
Service Vessels	89	443	22 050	12 282	9 768 309
Feed Producers	10	67	2 047 999	208 570	137 215 966
Feed Carriers	10	80	67 951	49 323	5 436 065
Cleaner Fish	25	151	10 840	3 183	1 636 883
Equipment	106	713	79 702	36 576	56 827 263
Processing	60	424	192 611	45 049	81 667 089
Packaging	9	65	141 908	58 019	9 224 045
Fish Health	38	268	91 904	13 138	24 630 200
NSB Equipment	73	524	97 843	35 278	51 269 906
Shipyards	22	146	88 672	25 982	12 946 179
Other Services	43	258	38 009	4 552	9 806 229
Total	745	4 752			693 375 870

Notes: Units is the number of individual legal entities. N is the number of observations (firm-years), floating prices.

Column (1) reports the number of individual entities in the data set. Column (2) shows the number of fiscal years (observations). The imbalance is evident since Column (1) multiplied with 8 (number of years during 2010-2017) is different from column (2) in most cases. Columns (3) and (4) report the average and median revenue in each segment across all years. Finally, column (5) displays the aggregate revenue over the entire period.

To summarize, the data set contains 745 individual legal entities with a total of 4,752 firm-year observations with an accumulated revenue of NOK 693.4 billion. I now finalize this chapter by evaluating the representativity of the data to secure the validity of my empirical estimates.

5.4 Representativeness of the Sample

This section follows the same structural layout as above; I start with the farming component before I move on to the non-farming component. Assessing the representativeness of the farming data is less complicated compared to the non-farming data since the true population capacity parameter in the former is known.[19] Table 7 reports the sample (S) relative to the population (P), with respect to licenses and sales.

Table 7. Representativeness of the farming sample

Variable	2010	2011	2012	2013	2014	2015	2016	2017
#Companies (S)	101	92	94	91	88	88	84	82
#Licenses (S)	670	657	634	688	685	683	743	683
#Licenses (P)	974	998	996	1 011	1 009	1 059	1 088	1 093
#Licenses (S in % of P)	69	66	64	68	68	64	68	62
Sales in GWEt (S)*	628	684	751	820	824	846	849	805
Sales in GWEt (P)*	883	998	1 161	1 102	1 179	1 223	1 174	1 158
Sales in GWEt (S in % of P)	71	69	65	74	70	69	72	70

Notes: # represents "number of". *numbers in thousands
Source: DoF (2018a), DoF (2019b), SSB (2019)

The first row of Table 7 shows the number of companies in the sampling year. The second row reports the number of licenses controlled by firms in the sample, and the third row reports the number of licenses in the population. The fourth row calculates the magnitude of the sample relative to the population. The fifth and sixth row reports sales in gutted weight for the sample and population, respectively. The seventh and final row calculates the sample sales relative to the population sales. As the table shows, the sample represents between 62 and 69 percent of all licenses and between 65 and 74 percent of the total Norwegian supply during the period.

As seen above, the sample consistently covers about two-thirds of the underlying farming population regarding the number of licenses and sales volume, which could suggest that the

[19] The DoF records all farming companies and associated capacity in the aquaculture register.

sample is representative. However, a relatively large share of the population is not necessarily a guarantee for representativity since it could contain, e.g., only the most profitable firms for some reason. Thus, to assess the representativity of the sample, one must consider the selection criteria and deem whether they are likely to omit important observations. As mentioned, the most prominent reasons the DoF excludes firms from their survey data set are incomplete (or missing) submission forms, intricate business structures, inactivity, and other unspecified reasons.

Considering the mandatory attendance in the survey, one may find it reasonable to expect the DoF to pursue companies that systematically fail to submit satisfactory submission forms or firms that consistently refrain from participating. Hence, one should expect that the composition of omitted firms according to the first criterion changes over time, and therefore it does not make the sample any less representative on average. The second criterion implies that certain companies have difficulties in separating farming operations from other activities, which could introduce a bias to the sample by only including well-defined companies. The third criterion omits inactive companies and does not introduce any bias. In fact, by failing to exclude inactive companies, one risks to, e.g., underestimate the return on invested capital by exaggerating the total invested capital that is involved in generating profits.[20] The last and final criterion is diffuse, and the DoF does not disclose any information about what it includes. On average, "other reasons" accounts for about 17 percent of all omitted observations and most certainly have the potential to bias the sample.

To assess the overall omitted observation bias, I run cross-checks against the aquaculture register combined with data from the Norwegian Food Safety Authority (lice register). According to my analysis, the DoF survey systematically omits certain firms that in total accounts for between 20 and 30 percent of the population in terms of licenses.[21] Unfortunately, I do not have sufficiently detailed information on these companies to include them in my resource rent analysis.[22] However, I do have enough information to calculate various financial ratios, which clearly shows that the profitability is in line with the results based on the sample firms.

[20] All else equal, by increasing the invested capital one effectively decreases the EP in eq. (2).
[21] The identity of companies in the survey is classified information based on a legal agreement with the DoF. For this reason, I cannot disclose the names of omitted firms either.
[22] I do not have access to detailed production data on these observations, e.g., kilograms produced or sold, specific revenue from sale of fish, etc.

Adding to the points made above, the sample shows great diversity and includes companies from all over the coast, and in all sizes. Altogether, the DoF survey seems to be representative of the population, and none of the exclusion criteria seem to introduce significant noise to the sample during the period 2010 to 2017.

The representativeness of the non-farming data is harder to assess since there is no official register of the actual population. However, Sintef, one of Europe's largest independent research organizations, published a study on the ripple effects from the aquaculture and fishery supplier industries in 2017 (Winther et al., 2017), that I can use as a reference point. In this study, the authors describe a somewhat similar data gathering strategy, and the result is a data set with 830 firms. The inclusion of fisheries is an important distinction, and I expect their database to contain more companies. The most apparent explanation is that first-order suppliers to the fisheries are often second-order suppliers to the aquaculture industry, e.g., echo sounding and navigation systems, cranes, and winches. I do not include second-order suppliers in my data set, thus reducing the sample size significantly. Under the assumption that a data set with 830 firms is representative for the population of firms in two industries, I find it reasonable to assume that my sample, which only includes aquaculture, is representative with its 616 firms (745 including farming).

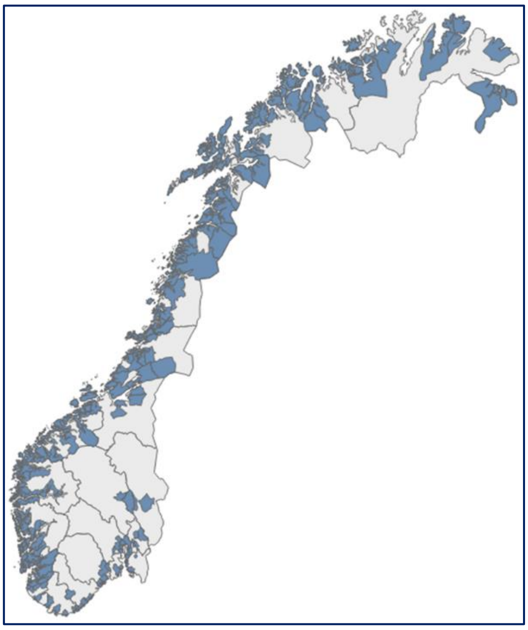
To further support my assumption, I compare my assessment of the historical performance of each segment (appendix 2) with the findings in the annual aquaculture analysis report by EY (2016, 2017, 2018). The similarities are striking regarding aggregate revenue in the sample, i.e., my sample corresponds to the one Ernst & Young uses for inference.

Altogether, the data gathering approach of non-farming companies seems to be appropriate for identifying industry players, and the sample appears equally representative as the data used in existing research. That said, by applying various selection criteria, such as only considering legal entities, I risk to omit players that are essential for daily farming operations, e.g., the local electricians, plumbers, carpenters, drivers, etc. that often follow a Norwegian legal form called "ansvarlig selskap" (liable company) where financial information is not publicly available. Furthermore, by excluding companies with less than two years of reported revenue, I risk excluding players that are involved in restructuring processes in addition to start-up companies that are essential for driving innovation. Contrary, by omitting firms without capitalized assets and only include companies where aquaculture is a significant business area, I ensure to incorporate companies that are actively involved in the aquaculture industry and have a real potential to capture rent. All the above arguments taken together, I find it reasonable to assume that the non-farming data is representative and will secure the reliability of my empirical results.

The final contribution of this subchapter is an assessment of the physical whereabouts of the entire sample (both farming and non-farming companies) to ensure geographical diversity. Figure 17 depicts the distribution of companies in the data set based on the legal address of the headquarter (HQ) on a municipality-basis. The sample includes approximately 45 percent of all municipalities (190 of 422) and 100 percent of all counties (18 of 18). The top five most important counties based on the number of registered entities are Hordaland (20.42 percent), Trøndelag (15.52 percent), Møre og Romsdal (15.24 percent), Nordland (13.99 percent), and Sogn og Fjordane (7.69 percent). The top five most prominent municipalities are Bergen (5.04 percent), Frøya (3.34 percent), Vikna (3.22 percent), Austevoll (3.22 percent), and Trondheim (2.94 percent). Although the location of the HQ does not necessarily represent the actual activity in each geographic area, the data set seems to be diverse and encompasses firms from most parts of the nation, which further strengthens the overall validity of the data.

Altogether, I take the above arguments, reference studies, and analysis as evidence in favor of the representativeness of the data set. This concludes my presentation of the data, and I now proceed to the empirical analysis, where I utilize the sample to estimate the resource rent, including rent shifting, in the industry.

Figure 17. Geographical distribution of the data set – municipalities



Notes: The map highlights all municipalities represented in the data set.
Source: BRC (2019), Author

6. Empirical Analysis

In this chapter, I report and discuss results from applying eqs. (9), (13), (14), and (15) to my data set. Followed by robustness tests of critical parameters that intend to elucidate the sensitivity of the results to changes in key parameters that cannot be measured with certainty by recalculating outcomes under alternative assumptions. The objective of my analysis is to report a reliable estimate range for the resource rent in the Norwegian aquaculture industry.

This chapter proceeds as follows. First, I present my estimate of the farming rent, followed by the rent shifting effects. Second, I provide estimates of the total resource rent in the industry for each period. Finally, I assess the uncertainty of the estimates through a sensitivity analysis, which contributes with an upper and lower bound to my concluding resource rent figures. For detailed information on all input variables used in this analysis, see appendix 2.

6.1 Resource Rent in Farming – Baseline Results

Table 8 reports the estimated rent when applying my data set, described in chapter five, to eq. (9). The realized resource rent in the farming segment is positive for all years except 2012, with a notable positive deviation in the two later years. In fact, the rent nearly tripled in 2016 compared to the previous year, followed by a minor correction of minus ten percent in 2017. For these two later years, the rent spiked due to high prices for the underlying commodity. Contrary, the negative rent in 2012 was a result of plummeting prices as a direct consequence of a Chilean volume rebound from the mentioned negative supply shock in 2009. Farmers make production decisions (volumes) three years prior to harvest, and thus face significant uncertainty concerning future prices. The high prices in 2009 and 2010 gave an incentive to produce (and sell) as much fish as possible. When the Chilean production volumes normalized in late 2011, it implied a short-term over-supply in the market that pushed prices down and seemingly below the breakeven levels of Norwegian farmers, i.e., the cost of exploiting the resource exceeded the benefit. Although one could argue that negative rents are a sign of inefficient extraction since the return to the resource is lower than the input, the production levels were rational (and efficient) at the time of decision (in 2009). If the resource rent remains negative for a sustained period, it may indicate inefficient exploitation, and the invisible hand of the market will make necessary adjustments, e.g., adjusting production levels, bankruptcies with associated redistribution of licenses from the least efficient to the more efficient players, etc. For this reason, one must consider extraction strategies on a long-term basis, as Figure 18 clearly illustrates.

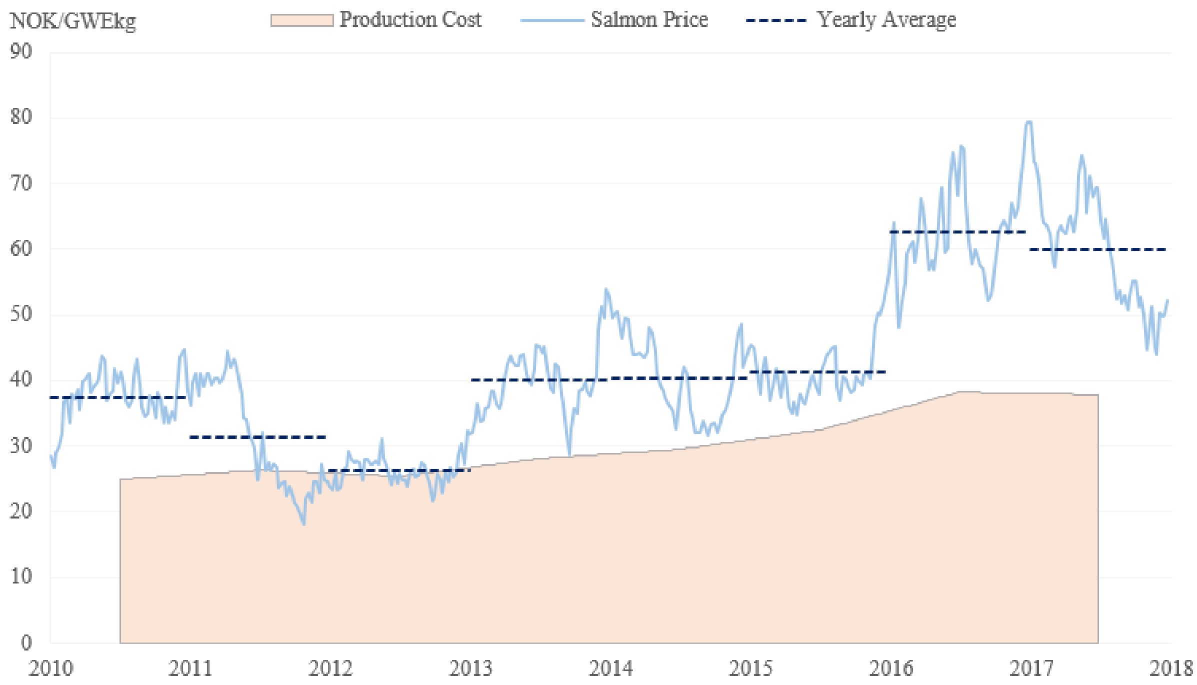
Table 8. Resource rent in the farming segment

Variable	2010	2011	2012	2013	2014	2015	2016	2017
rf_t	8.64	1.99	-1.25	6.97	6.22	5.02	18.50	16.81

Notes: All numbers are in NOK/kg and floating prices
Source: Author

When using resource rents as a measure of national wealth, researchers often replace negative values with non-negative values (zero), based on the argument that the management of the resources had other objectives or goals than maximizing the rent, e.g., coastal population (Lindholt, 2000). In Norway, the license holders are strongly encouraged to ensure local jobs along the coast and actively prevent depopulation (Ministry of Trade Industry and Fisheries, 2005). Thus, one can expect farming firms to operate with somewhat undesirable company structures, though to a minor extent, and consequently have a higher than necessary production costs at the expense of lower resource utilization.

Figure 18. The spot price of salmon and production costs, floating prices.



Source: NASDAQ (2019), DoF (2018a), Norsk Standard (2012), Author
Note: The production cost includes: smolt, feed, personnel, depreciation, net financial expenses, insurance, processing and transportation, and other operating costs. The production cost does not account for the opportunity cost of capital.

The only empirical analysis available for comparison with Table 8 is the Flaaten and Pham (2019) study. As mentioned, they estimate a resource rent of NOK 15.774 billion, or NOK 18.57 per GWEkg, based on a sample of 68 percent of the farming population. Although the authors apply a different approach, the estimates seem to coincide very well with mine. Further, Flaaten and Pham (2019) also calculate the value of a license to NOK 138 million, or NOK 176 thousand per tonne of licensed capacity, in 2016. I compute a comparable figure of NOK 139.9 million, or NOK 179.4 thousand per tonne of licensed capacity, in 2017 (see Appendix 3). Finally, the license value from my analysis is very close to the average price of NOK 195 thousand per tonne of licensed capacity, paid at the 2018 auction (DoF, 2018). The fact that both license value estimates seem to be in the ballpark of the realized price in the most recent auction indicates that farmers are acting rationally.

It follows from economic theory that an investor (farmer) should only accept positive net present value investments. If this does not hold, then the value-added (or real growth) from the investment is less than or equal to zero. For this reason, the rational investor is willing to pay exactly the expected economic profit (resource rent) from the license to participate in the market. My analysis and the realized prices at the 2018 auction show that the farming firms are willing to pay the full benefit from new capacity in advance.[23] I regard this behavior as strong evidence in favor of extensive resource rent in the industry, and farmers clearly acknowledge the benefit of having privileged access to common property rights.

Altogether, the analysis suggests significant resource rent in the farming segment, although with great volatility. The two later years of the study have proven particularly lucrative because of soaring fish prices. I now proceed to investigate potential rent shifting effects by addressing the possibility of rent capture in other parts of the value chain.

[23] Which is equivalent to paying 100% resource rent tax.

6.2 Rent Shifting Effects – Baseline Results

Table 9 reports the estimated rent shifting from applying my data set to eq. (13). Although several cost groups report negative effects, the aggregate effect is positive for all years during the period. The table discloses multiple notable developments. First, the shifting effects vary substantially between various cost groups, with the most significant variation in feed and other operating costs. Second, depreciation and other operating costs are the only groups that remain positive throughout the entire period. Third, the most prominent contributor to rent shifting in 2010 reports a strongly negative effect in 2017. Fourth, other operating costs is the largest yearly contributor in six out of eight years. In addition, other operating costs are, on average, substantially larger than any other cost group.

Table 9. Rent shifting effects

Cost variable	2010	2011	2012	2013	2014	2015	2016	2017	Average (2010-17)
Smolt	0.03	0.08	0.03	-0.07	0.02	-0.01	0.11	-0.19	0.00
Feed	0.42	0.17	0.29	-0.08	-0.27	0.01	0.28	-0.19	0.08
Depreciation	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01
Other operating	0.17	0.21	0.19	0.30	0.44	0.58	0.76	0.41	0.38
Process & Transportation	-0.04	0.03	0.03	-0.04	0.05	0.08	0.06	0.05	0.03
rs_t	0.58	0.50	0.54	0.13	0.24	0.67	1.22	0.09	0.50

Notes: All numbers are in NOK/GWEkg and floating prices
Source: Author

The findings in Table 9 suggest that other parts of the value chain capture parts of the resource rent. As a result, assessing the resource rent in the industry solely based on the farming segment introduces a bias to the conclusion.

As mentioned, according to economic theory, one would expect that positive economic profits encourage entry to the industry (or segment). In the case of the farming segment, entry is not possible, and therefore positive profits can also persist in the long run. In the remaining parts of the value chain, however, there are few barriers to entry and economic profits should revert to zero over time. The reversion time depends on at least three factors. First, how quickly existing players can adjust supply to account for changes in demand. Second, how rapidly potential newcomers can establish a competing firm and at which cost. Last, the managerial practices in farming firms, e.g., contract lengths, cost management focus, quality preferences, personal relationships, etc. The sum of these factors determines the bargaining power of suppliers, which drives the rent shifting effects. In the remainder of this subchapter, I attempt to highlight these effects by narrowing in on the two most significant cost groups, namely feed and other operating costs.

Under the assumption that all players are rational and thus continuously seek to maximize profits, one should expect to find most explanatory variables for positive rent shifting in fundamental conditions, e.g., exogenous supply or demand shocks. The feed cost group consists of two segments, namely feed carriers and feed producers. Table 10 shows an outtake from the analysis in appendix 2, where the return on invested capital (ROIC) is a measure of the realized return on invested capital.

Table 10. Profitability in the Feed cost group 2010-2017

Segment	Variable	2010	2011	2012	2013	2014	2015	2016	2017
F. Producers	ROIC (%)	22.02	16.05	17.94	9.98	6.27	9.46	15.06	5.66
	WACC (%)	10.76	10.94	10.03	11.30	11.38	8.85	7.85	8.84
F. Carriers	ROIC (%)	7.65	7.70	8.02	9.68	6.93	8.42	6.47	7.01
	WACC (%)	12.03	12.24	12.56	11.87	11.38	9.96	9.79	10.12

Notes: Return on invested capital (ROIC) is defined as ROIC = EBIT/(Yearly average IC). One can interpret a ROIC of 22% as earning 0.22 NOK per 1 NOK invested in operations.
Source: Author

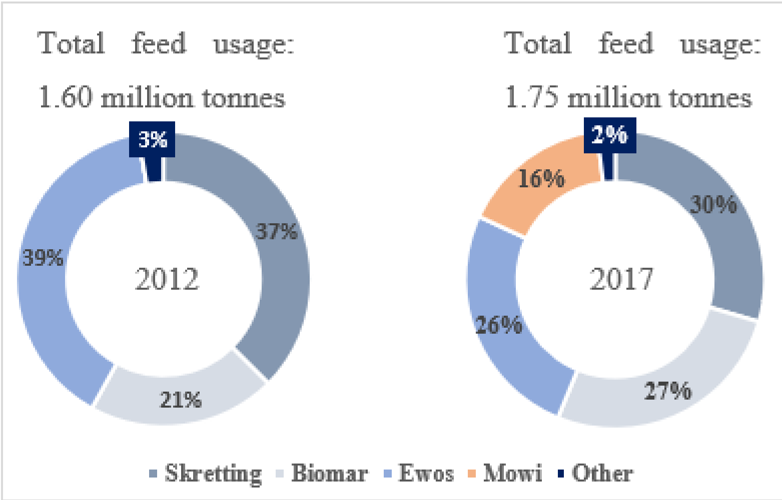
As seen in table 10, the feed carriers have yet to contribute positively to rent shifting.[24] Consequentially, any positive rent shifting effects must originate from feed production. The primary reasons for the low margins in the feed carrier segments are mostly low tonnage utilization combined with long freight distances and expensive vessels (invested capital relative to income potential). The first two reasons stem from the fact that (until recently) each vessel only carries feed from one specific producer, while one farming firm may order feed from several producers to neighboring production sites. Whereas modernization, e.g., silo-based cargo systems with automated offloading systems as opposed to carrying feeding bags and offloading by diggers/cranes, implementation of dynamic positioning when offloading as opposed to tying the ship to a feed barge, etc. explain the latter (NSK Shipping AS, 2019, Egil Ulvan Rederi AS, 2019). For these reasons, the industry does not encourage entry and existing players are currently adjusting supply through consolidation and restructuring (e.g., carrying

[24] ROIC is consistently lower than WACC (realized return is lower than required)

feed for more than one producer at once (Brundtland, 2019)), i.e., the market is currently adjusting to reach equilibrium and thus revert rents from negative to zero.

The feed producer segment was, for a long time, an established oligopoly consisting of three large suppliers: Skretting, Biomar, and Ewos. In aggregate, the demand for pellets is a function of licensed capacity and its utilization (the average standing biomass). As a result, the established produces only have incentives to make incremental capacity investments, unless new investments can substantially change production costs and in turn, increase market shares of the producers. For this reason, entry to this market is very expensive because new entrants must be able to produce substantial quantities at lower prices than established firms to acquire market shares. That said, the market suffered an exogenous supply shock in 2012 that rocked the market. Mowi, the world's largest salmon producer, proclaimed its strategy to become feed self-sufficient within 2014 (Mowi ASA, 2012). Following the announcement, established feed producers faced significant overcapacity and lower utilization from 2014 and onwards. The announcement materialized in substantial downward pressure on margins, especially on homogenous products ("regular" pellets). Adding to the weakened bargaining power was also the low salmon price in 2012, which possibly triggered intensified cost management focus in the farming firms. The events in 2012 are observable in Table 9, where the average rent shifting of feed is NOK/GWEkg 0.29 during 2010-2012, and NOK/GWEkg -0.08 during 2013-2017. From 2014 onwards, the profits in feed production are possibly approaching equilibrium (P = MC) on regular pellets, and most value-added (rent) stems from heterogeneous products, particularly in times of challenging biological farming conditions, e.g., as seen in 2015/2016. Figure 19 depicts Mowi's impact on the respective market shares.

Figure 19. Market shares in the Norwegian fish feed market



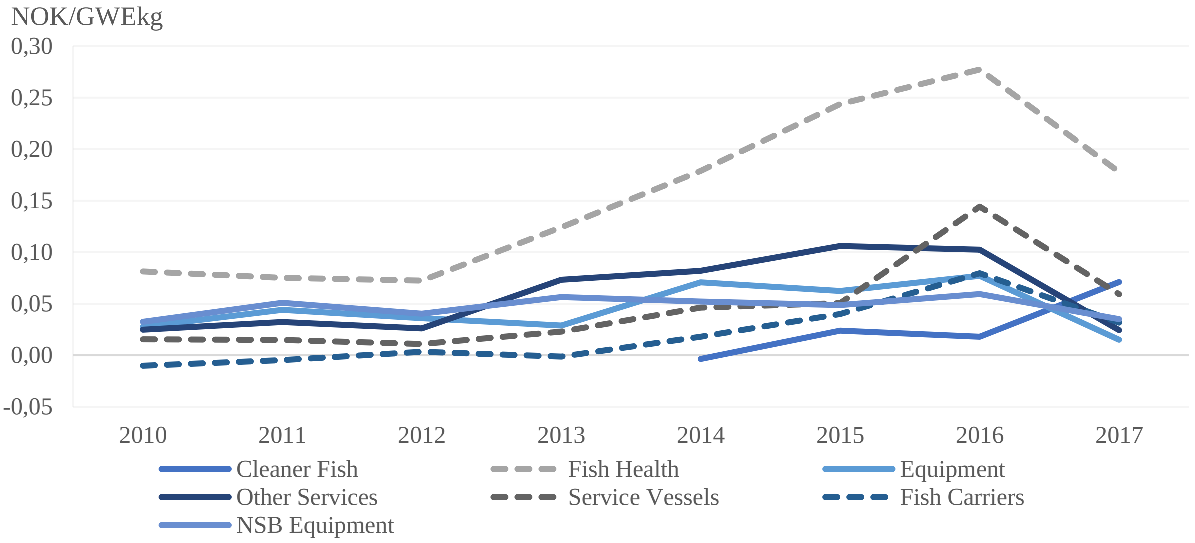
Notes: Market shares are based on revenues and not quantities due to confidentiality considerations.
Source: BRC (2019), DoF (2019b)

To summarize, the feed market has changed drastically during the period, and the present market is characterized by fierce competition with associated margin pressure. Thus, one should only expect modest rent shifting effects going forward, primarily driven by heterogeneous products, such as specialized growth feed, medical feed, etc., which carries a potential for price premiums. That said, the future may hold new shocks with associated elevated rent shifting, for example, form increased feed demand related to land-based and offshore farming technologies.

Clearly, there have been significant exogenous shocks in the feed market historically, and the shifting effects seem to behave according to economic theory by reverting towards zero. Now, I turn the attention towards other operating costs to see if the same mechanisms apply.

The other operating cost group consists of seven segments, Cleaner Fish, Fish Health, Equipment, Non-sea-based Equipment, Service Vessels, Wellboats, and Other Services. Figure 20 depicts the contribution from each segment to the total rent shifting effect in the other operating cost group during 2010-2017. The figure shows that five out of seven segments peak in 2016, and six out of seven reverts in 2017.

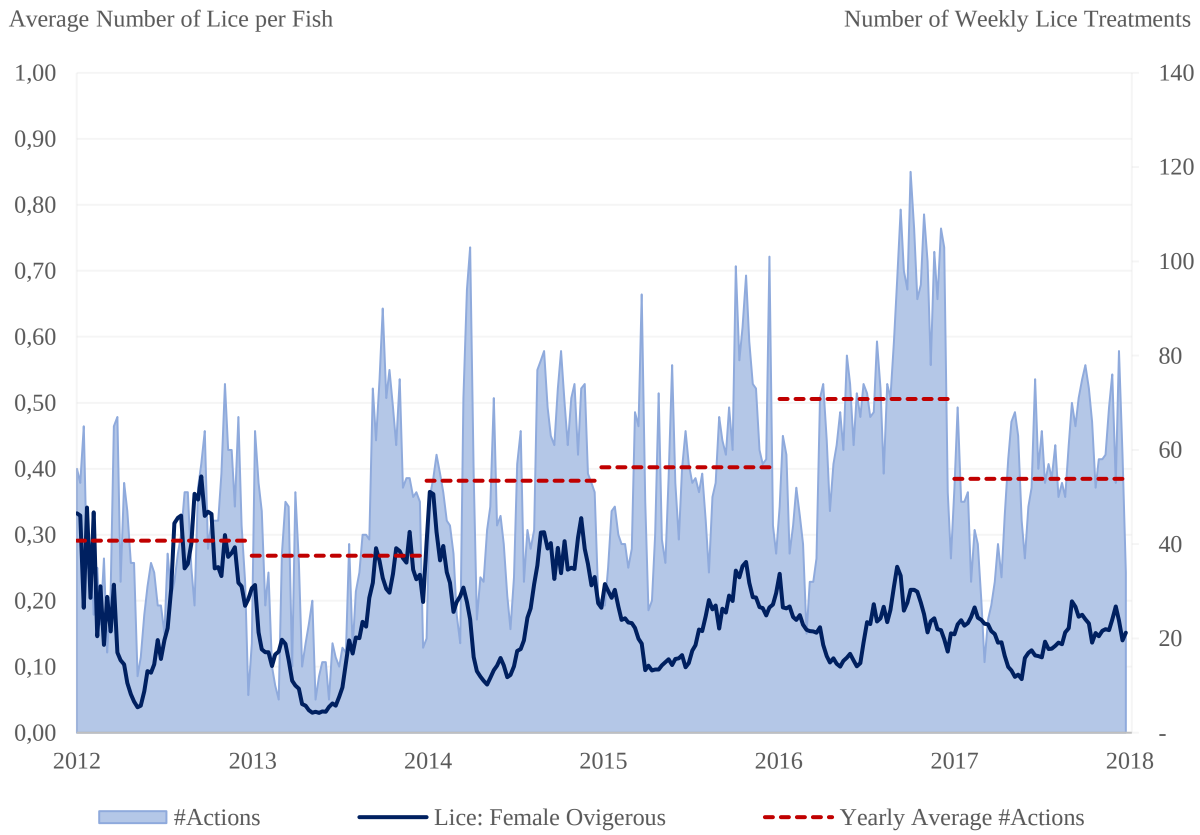
Figure 20. Rent-shifting effects: Other operating costs by segment



Notes: Floating prices. Shows segment-based contribution to the other operating cost group rent shifting effects.
Source: Author

Considering the coordinated behavior among most of the segments, one should expect to find at least some common denominators across the fields. Analyzing the financial records of farming firms reveals that farmers post most of the treatment-related costs as other operating. Thus, a sensible point of departure for understanding the shifting effects is to consult treatment data. Figure 21 depicts the average number of lice per fish, together with the number of weekly treatments against lice on a national level during 2010-2017. Treatments include bath, mechanical, and medical feed (slice). The data shows that, on average, 2016 was the busiest year with respect to number of treatments. In fact, the number of treatments was 26 percent higher in 2016 compared to 2015, thus facilitating higher demand for lice-related goods and services. Increased demand, all else equal, improves the bargaining power of suppliers and one expects to see higher prices in the short-run. This mechanism coincides well with the rent shifting effects in Figure 20. However, Figure 20 also provides evidence of adaptation to increased demand, which materializes in a strong reversion effect in 2017.

Figure 21. Average lice levels and number of treatments in Norway during 2010-2017.

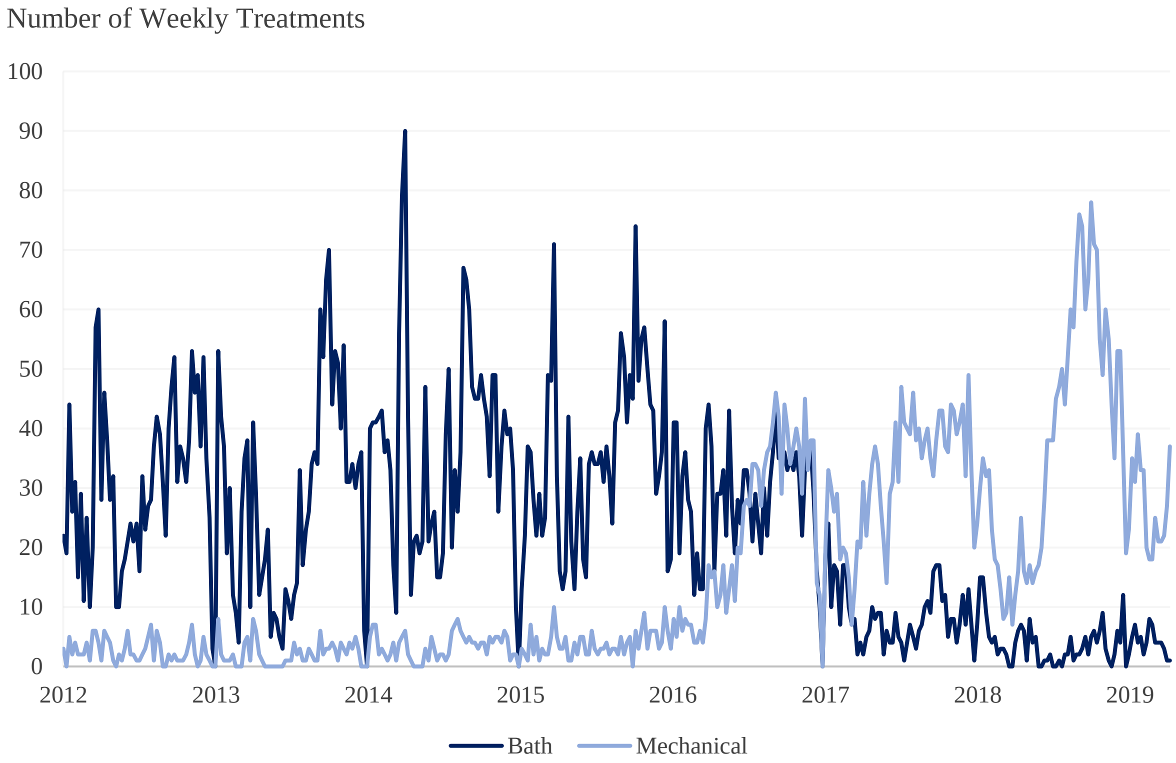


Notes: Number of actions includes treatments (mechanical and bath), slice, and the number of cleaner fish releases.
Source: Mattilsynet (2019a)

The duration of positive profits depends on how rapid the supply side manages to establish a new equilibrium, i.e., how quickly existing, or aspiring, firms can increase supply to match a higher demand. In the fish health segment, building capacity depends on the service or good in question. It takes several years to educate new veterinarians (or fish health biologists), and even longer to develop and receive approval for new remedies. Further, several firms may even hold important patents, which allow for positive profits over a prolonged period. However, Figure 20 shows a gradual improvement of the rent shifting effects from 2012 to 2016 before a strong reversion in 2017. This development suggests that it takes time to build capacity in this field, but it may be approaching demand in 2017.

Continuing the analysis by studying service vessels shows a similar trend. Adjusting supply in the service market depends on how long it takes to build a new vessel, which for most vessels are from four months to a year. The economic profits of the Service Vessel segment are positive for all years during 2010-2017. A major explanation for the sustained profits is the introduction of mechanical delousing techniques such as Thermolicer, Skamik, Optilicer, and Hydrolicer. A typical mechanical treatment requires a treatment vessel (e.g., a wellboat, barge, or designated ship) in addition to 1-3 service vessels, which is significantly more than a comparable bath treatment where farmers often use one service vessel and 2-3 small boats equipped with capstans[25]. Figure 22 shows the transition from bath to mechanical treatment methods, and it seems to coincide with the rent shifting effects.

Figure 22. The transition from bath to mechanical treatment methods



Notes: The figure shows the total number of weekly bath and mechanical treatments from 2012 to 2019.
Source: Mattilsynet (2019a)

Moreover, adding to the points made above is also other exogenous shocks to the demand side such as a greater need for mooring work and inspections due to tightened regulations.

Leaning on economic theory, one should expect to see an increase in both new entrants (new players) and new vessels from existing firms. The empirical evidence confirms substantial supply-side activity. In 2010, the number of vessels in my sample is 94 compared to 248 in 2017, and 59 percent of the new supply entered during 2015-2017 (92 vessels). In addition, there is also a shift in behavior over the period. During 2010-2014, 16 percent of new builds was above fifteen meters of length, whereas 39 percent of all new builds are above 15 meters

[25] A capstan is a deck equipment used to pull ropes with tension between 1-3 tonnes (normally).

of length during 2015-2017.[26] There is strong evidence that the supply side is adjusting, and future rent-shifting effects should revert even further as supply approaches demand.

The wellboat segment also benefits from increased demand from treatments. Many wellboat firms install mechanical delousing machines on their ships in addition to treating lice with fresh water in the freight tanks (wells). In contrast to the service vessel segment, the number of wellboats remains stable during the period. Table 11 shows the capacity of the standing Norwegian wellboat fleet during 2010-2017.

Table 11. The estimated capacity of the Norwegian wellboat fleet during 2010-2017

Year	Average Well-Capacity (m^3)	Average Gross Tonnage	Number of Ships
2010	946	893	62
2011	957	912	58
2012	980	937	60
2013	1 095	1 051	56
2014	1 184	1 151	58
2015	1 252	1 232	58
2016	1 392	1 399	60
2017	1 689	1 768	66
CAGR (%)	9	10	1
Growth (%)	78	98	6

Notes: Based on a sample of approximately one hundred new builds during 1996-2018.
Source: Aas Mek Verksted AS (2019), DoF (2019b), Mattilsynet (2019b), NIS (2019), NOR (2019), Refvik (2005-2019)

The large growth in well-capacity shows how the supply side is adjusting to increased demand. However, by refraining from increasing the number of ships, the industry manages to sustain a certain level of bargaining power since one ship can only be on one locality at once. Further, farming firms tend to charter vessels on semi-long contracts (often two years), which predefine prices over the entire period. That said, farmers also hire substantial capacity through the spot market in times of tough biological conditions. Besides, one may also speculate that running a wellboat company relies on established relationships and trust, given the large values they carry

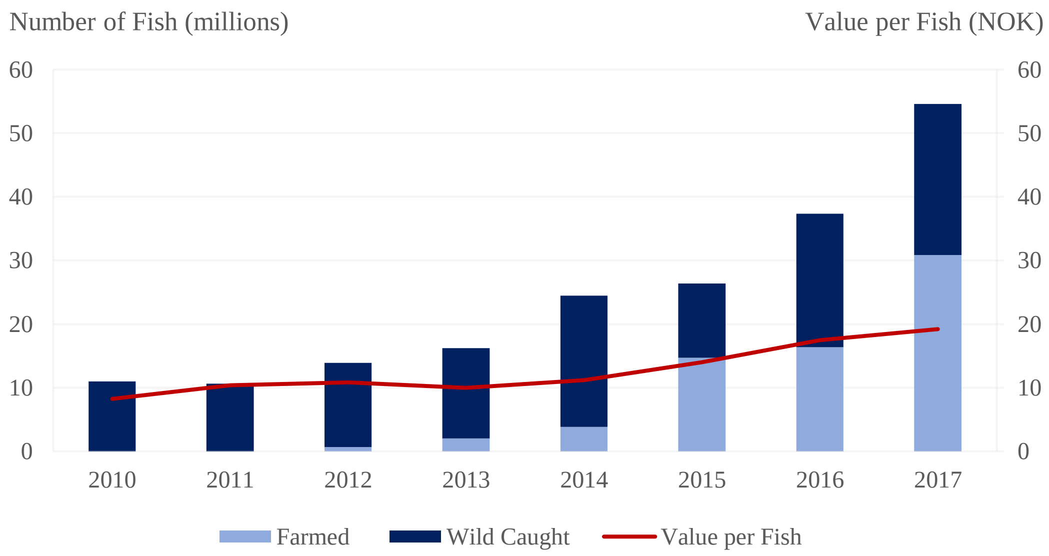
[26] 15 meters is a threshold for ship classification, where above 15 meters requires, e.g., certificates of competence, a minimum crew of three people (normally), more safety equipment, stricter reporting standards, etc.

on behalf of farmers. As a result, wellboats may have lower price sensitivity than other segments.

Although table 11 shows that the number of vessels remains stable over the period, there is now significant ship-building activity among farmers. This could be an effort to reduce margins, or simply because they use wellboats to such extent that it is reasonable to have their own. Furthermore, there is also an increasing interest in processing vessels, which naturally can carry significantly higher fish volumes per gross tonnage of ship size. Altogether, the wellboat segment will most likely experience a significant supply increase in the number of vessels going forward, which carries the potential to reduce the existing bargaining power from relatively few vessels in operation.

The cleaner fish segment is a rather new constituent to the professional supplier industry. Historically, local fishers around the coast caught wild living cleaner fish as a side-job during the summer months and sold it to farmers. In recent history, however, the segment has changed drastically. Today, more than fifty percent of the cleaner fish in Norwegian pens stems from systematical farming in sizable onshore factories (DoF, 2019b). Figure 23 depicts the introduction of farmed cleaner fish in 2012-2013.

Figure 23. Cleaner fish usage during 2010-2017



Notes: Shows the number of cleaner fish released and the associated value during 2010-2017 (floating prices)
Sources: DoF (2019b)

During the period of interest, the volume has increased by nearly 400 percent, with a growth in value per fish of 133 percent in nominal terms. Implicitly, there has been a remarkable latent demand for cleaner fish in recent years. A possible explanation is that cleaner fish is the most effective preventive tool in the battle against lice. Using more cleaner fish implies (normally) fewer treatments, which often carries considerable mortality (Hjeltnes et al., 2019). Ever since 2014, the cleaner fish firms have captured rent through strong bargaining power. According to economic theory, this should attract new entrants, which it has. In 2012, there were five companies with a total of 15 licenses, compared to 27 companies and 45 licenses in 2017 (DoF, 2019a). Despite the drastic increase, there are no signs of downward pressure on margins in the segment yet (appendix 2). However, one should expect to see intense establishment activity going forward, and margins will come down as producers satisfy demand and start competing on price.

That said, one could speculate if the authorities will dampen the growth in capacity due to health problems in the cleaner fish factories with alarming growth in antibiotics consumption (Grave and Helgesen, 2018). This trend could define barriers to entry in line with those in salmon and trout farming until the industry develops better technology, gains knowledge, and improves procedures. Another potential threat to future growth is increased focus on animal welfare for the cleaner fish, which under the present farming regime is poor (Hjeltnes et al., 2019). This latter factor could contribute to lower demand, which will impose downward pressure on margins (and thus reduce rent shifting).

To summarize, my analysis shows that fish prices are the primary driver for increased farming rent, whereas increased demand for underlying goods and services is the most important driver for rent shifting effects. However, one can also speculate whether high fish commodity prices itself provides an opportunity for suppliers to negotiate better deals, and thus capture rent over extend periods even if demand were to fall (depending on contract length). Conversely, lower fish prices may lead to a lagged reduction in rent shifting effects due to contractual commitment negotiated at higher prices.

Overall, economic theory is well suited to explain the development in both farming rent and rent shifting effect. Therefore, one should expect lower rent shifting going forward until new positive demand or negative supply shocks occur, considering the vast capacity build-up in most segments, whereas the farming rent mostly depends on the fish price and is harder to predict. I now proceed to calculate the aggregate resource rent in the industry by combining the results from above in line with eq. (13) and (14).

6.3 Total Resource Rent – Baseline Results

Table 12 reports the baseline estimates of the total resource rent in the Norwegian aquaculture industry. Column (1) is the realized quantity sold by Norwegian farming firms in the respective years. Column (2) is the output from eq. (14) and represents the total resource rent on a per kilogram basis. Column (3) shows the total resource rent in the industry. Column (4) and (5) splits the results from column (3) into farming rent and rent shifting, respectively. As seen in the table, aggregated resource rent in the industry is positive for all years except 2012, i.e., the rent shifting effects are not large enough to weigh-off for the negative framing rent.

Table 12. Resource rent in the Norwegian aquaculture industry – baseline results

	GWEt (000)	NOK/GWEkg	NOK (m)	NOK (m)	NOK (m)
Year	Sold fish	eq. (14)	eq. (15)	Farming	Shifting
	(1)	(2)	(3)	(4)	(5)
2010	883	9.22	8 146	7 632	514
2011	998	2.49	2 490	1 986	504
2012	1 161	-0.71	-819	-1 451	632
2013	1 102	7.1	7 817	7 678	139
2014	1 179	6.46	7 623	7 336	287
2015	1 223	5.69	6 952	6 139	813
2016	1 174	19.72	23 150	21 719	1 431
2017	1 158	16.9	19 565	19 467	99
Total	8 879	8.44*	74 925	70 506	4 418
CAGR (%)	4	9	13	14	-21

Notes: *weighted average using sold fish as weights. Floating prices.

My model estimates an accumulated resource rent of NOK 74.92 billion during 2010-2017, with a yearly growth rate of 13 percent. Approximately 94 percent ascribes to the farming segment, and the remaining 6 percent is rent shifting. The results indicate that measuring resource rent in the aquaculture industry based on the farming segments alone suppresses the actual rent, i.e., the costs recorded in the financial statements of the farming firms do not convey the real cost of exploiting the resource.

6.4 Sensitivity Analysis

In this subchapter, I evaluate the robustness of my baseline estimates by recalculating eq. (9), (13), (14), and (15), under two alternative scenarios concerning WACC: low and high. The low discount rate scenario applies a fixed WACC of four percent to all segments irrespective of different risk profiles. The figure originates from the official guidelines for capital budgeting on public investments in Norway (NOU2012:16). Although its relevance for decision making in private companies is rather questionable since it fails to account for the firms' different exposure to systematic risk, it is still used in empirical research (Greaker et al., 2017). In the high discount rate scenario, I add ten percentage points to the empirically estimated capital costs, which on average implies a near doubling (98.2 percent increase) of the WACC. It is essential to note that doubling the cost of capital is equivalent to doubling the capital base, holding the cost of capital constant. Implicitly, a WACC-based sensitivity analysis is equivalent to testing based on IC, all else equal. Table 13 reports the various WACCs used in each scenario.

Table 13. WACC used in each scenario

Segment	Scenario	2010	2011	2012	2013	2014	2015	2016	2017
	High (%)	20.68	20.93	20.06	20.88	20.33	18.55	17.93	18.77
Farming	Base (%)	10.68	10.93	10.06	10.88	10.33	8.55	7.93	8.77
	Low (%)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
	High (%)	20.63	20.68	19.77	20.75	20.50	18.59	18.00	18.98
Other*	Base (%)	10.63	10.68	9.77	10.75	10.50	8.59	8.00	8.98
	Low (%)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00

Notes: *Represents a weighted average across all segments using revenue as weights for illustrative purposes. I apply segment-specific WACCs in the analysis (see appendix 2).

In line with the baseline analysis, I initiate by evaluating the farming rent estimates, followed by rent shifting effects before I conclude with the total resource rent.

6.4.1 Farming Rent

Table 14 reports the farming rent from re-estimating eq. (9) under the additional scenarios. Estimating the model subject to the low-specifications returns positive figures for all years, including 2012. Conversely, using the high discount rate transforms 2011 to negative. Both outcomes portray an underlying uncertainty contained in the input variables, WACC/IC. That said, applying the high discount rate inflicts significant stress to the estimates by increasing the median WACC/IC by 98.08 percent. The increase materializes in a 53.68 percent drop in the rent estimates, i.e., a change in WACC/IC leads, all else equal, to a considerably lower change in rents. As a result, one can interpret the results as robust to changes in model parameters, and thus provides solid suggestive evidence in favor of substantial rent in the framing segment.

Table 14. Sensitivity analysis of the resource rent in farming

Scenario	2010	2011	2012	2013	2014	2015	2016	2017
Low	10.72	4.09	0.70	9.23	8.63	6.71	19.98	18.83
Baseline	8.64	1.99	-1.25	6.97	6.22	5.02	18.50	16.81
High	5.51	-1.04	-4.46	3.67	2.44	1.31	14.72	12.55

Notes: All numbers are in NOK/GWEkg (floating prices).

6.4.2 Rent Shifting

Table 15 shows the rent shifting effects from re-estimating eq. (13) under the additional scenarios. As seen in the three last rows of the table, using the high discount rate returns negative values in aggregate for all years during 2010-2017. However, there are large differences between the various cost groups. Other Operating and Depreciation shows considerable robustness and remains positive over the entire period, which illustrates the bargaining powers of the segments in the cost group. They manage to profit extensively on the ongoing biological issues in the industry and thus captures the most rent of all cost groups. Further, the modest margins in the feed group are readily visible from the strongly negative value in 2017. An even more strongly negative segment is smolt. I did not comment on smolt in the above analysis due to its close integration with farming firms, and issues with intra-firm transactions arise. That said, the smolt group also contains the Roe segment, which benefits from high barriers to entry from restricted access to vast repositories of genetic material (from the 70s and forwards). For this reason, Roe companies still capture rent, but smolt firms weigh substantially more in the cost group value, which yields an overall negative contribution to rent shifting.

Table 15. Sensitivity analysis of the rent shifting effects

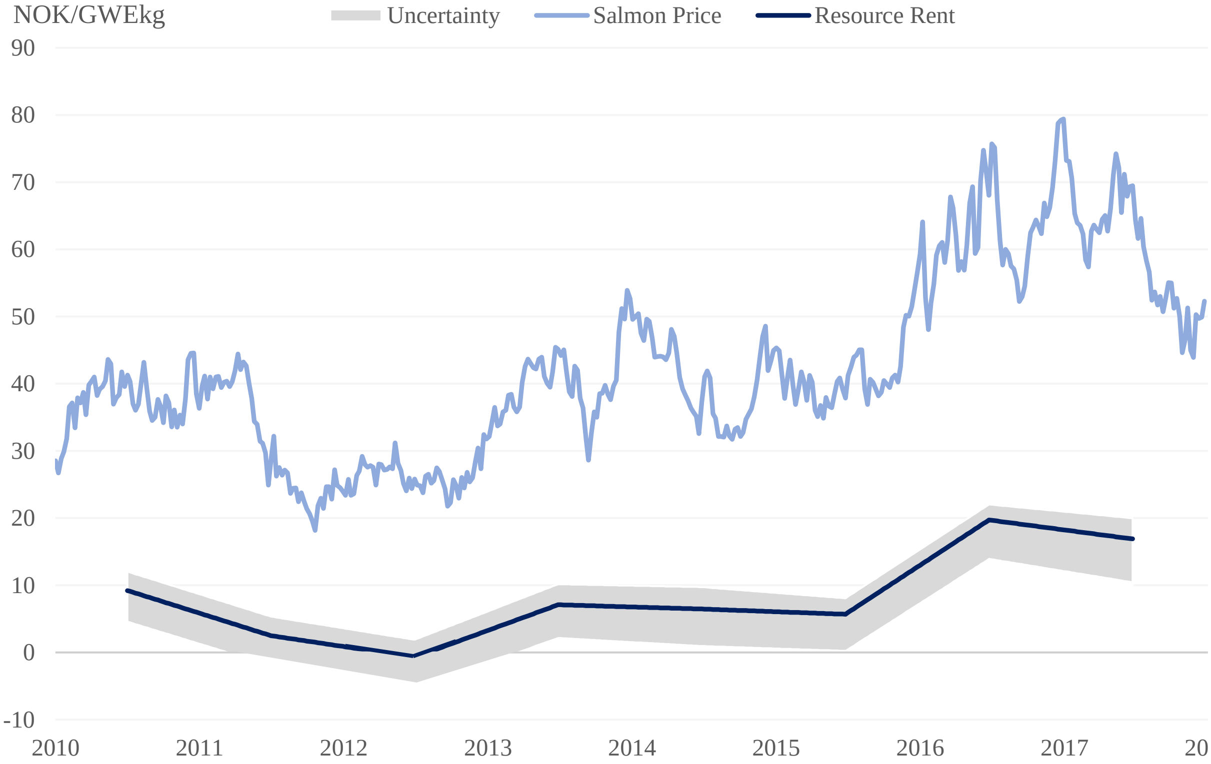
Scenario	Cost variable	2010	2011	2012	2013	2014	2015	2016	2017
Low	Smolt	0.28	0.35	0.23	0.17	0.28	0.23	0.38	0.17
	Feed	0.75	0.51	0.60	0.30	0.13	0.27	0.53	0.12
	Depreciation	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01
	Other Operating	0.26	0.29	0.27	0.46	0.59	0.73	1.03	0.75
	Process & Transportation	0.02	0.08	0.08	0.00	0.09	0.12	0.10	0.10
Baseline	Smolt	0.03	0.08	0.03	-0.07	0.02	-0.01	0.11	-0.19
	Feed	0.42	0.17	0.29	-0.08	-0.27	0.01	0.28	-0.19
	Depreciation	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
	Other Operating	0.17	0.21	0.19	0.30	0.44	0.58	0.76	0.41
	Process & Transportation	-0.04	0.03	0.03	-0.04	0.05	0.08	0.06	0.05
High	Smolt	-0.35	-0.26	-0.30	-0.38	-0.35	-0.44	-0.40	-0.83
	Feed	-0.05	-0.30	-0.20	-0.58	-0.83	-0.51	-0.30	-0.81
	Depreciation	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
	Other Operating	0.05	0.09	0.06	0.08	0.22	0.27	0.18	-0.21
	Process & Transportation	-0.43	-0.31	-0.40	-0.49	-0.39	-0.25	-0.12	-0.11
Low	Total	1.31	1.25	1.19	0.94	1.10	1.37	2.05	1.15
Baseline	Total	0.58	0.50	0.54	0.13	0.24	0.67	1.22	0.09
High	Total	-0.78	-0.77	-0.83	-1.37	-1.34	-0.93	-0.64	-1.96

Notes: All numbers are in NOK/kg floating prices.

6.4.3 Total Resource Rent

Altogether, the farming rent shows significant strength, and so does some of the cost groups in the rent shifting effects. I take the above analysis as strong evidence in favor of both substantial farming rent and the existence of shifting effects. For this reason, I stand by my conclusion that estimating the resource rent in the aquaculture industry solely based on farming accounts suppresses the resource rent, i.e., other parts of the value chain do capture rent, and over the study period, particularly the other operating cost group. Figure 24 plots the resource rent from eq. (14) with uncertainty (high and low discount rate), and table 16 shows the total rent in the Norwegian aquaculture industry.

Figure 24. Total resource rent with uncertainty together with the salmon price



Notes: All numbers are in NOK/kg (floating prices). Uncertainty represents the high and low scenarios.

The low and high discount rate represents the upper and lower bound of the uncertainty field, respectively. Whereas the former is fixed at four percent throughout the period, the latter ranges between 17 and 28 percent for each segment with an aggregate weighted average of about 20 percent yearly. A discount rate of 20 percent on a company level is by most standards considered a very high rate, even higher than what Wood Mackenzie (2018) finds in the most uncertain projects in the petroleum industry, exploration (at about 19 percent before tax). As clearly seen in the figure, despite the severe stress form the high discount rate, the rent remains positive for all years except 2011 (2012 was already negative at base case).

Table 16. Total resource rent in the Norwegian aquaculture industry with uncertainty

		rr_t			RR_t		
Year	Sold Fish	Low	Baseline	High	Low	Baseline	High
	GWEt (000)	NOK/GWEkg	NOK/GWEkg	NOK/GWEkg	NOK (m)	NOK (m)	NOK (m)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
2010	883	12.03	9.22	4.73	10 631	8 146	4 181
2011	998	5.34	2.49	-1.81	5 331	2 490	-1 809
2012	1 161	1.89	-0.71	-5.29	2 197	-819	-6 143
2013	1 102	10.17	7.1	2.3	11 201	7 817	2 533
2014	1 179	9.73	6.46	1.1	11 476	7 623	1 294
2015	1 223	8.08	5.69	0.38	9 879	6 952	469
2016	1 174	22.03	19.72	14.08	25 867	23 150	16 526
2017	1 158	19.98	16.9	10.59	23 143	19 565	12 266
Total	8 879	11.23*	8.44*	3.30*	99 724	74 925	29 318
CAGR	4 %	8 %	9 %	12 %	12 %	13 %	17 %

Notes: All numbers are in NOK floating prices
*weighted average using GWEt as weights.
Sources: Directorate of Fisheries

Column 1 reports the quantity of fish sold by Norwegian farmers in each period in GWE-tonnes. Column (2) to (4) displays the results from estimating eq. (14) in each scenario and represents, by specification, total resource rent in the industry per GWEkg. Finally, column (5) through (7) reports the total resource rent in the industry from eq. (15). The baseline estimate is NOK 74.9 billion, but applying a low discount rate yields NOK 99.7 billion, which represents an increase of 33 percent. The high discount rate, on the other hand, returns an estimate of NOK 29.3 billion, which equals a 61 percent reduction. However, both scenarios imply significantly larger changes in input variables compared to the corresponding rent change, which suggests robust results.

My concluding estimate of the resource rent in the Norwegian aquaculture industry is NOK 74.9 billion during 2010-2017, with an upper and lower bound of NOK 99.7 and 29.3 billion, respectively.

7. Conclusion

In this thesis, I investigate the generation of resource rent in the Norwegian aquaculture industry with an emphasis on salmon, trout, and rainbow trout species. Whereas past economic research on resource rent assumes that the license holders capture the entire rent, my thesis analyze rent by also allowing for rent generation in other parts the value chain, which I term rent shifting. By utilizing and extending a basic model for computing economic profits, I develop a framework that consists of a farming rent component and a rent shifting component, which on aggregate define the total resource rent in the industry. Using firm-specific accounting data on more than seven hundred companies from 2010 to 2017, I find that the industry generates substantial resource rent. Specifically, the resource rent totals NOK 74.9 billion over the eight years with an average farming rent and rent shifting of about NOK 9 and 0.5 billion annually, respectively.

My study indicates that fish prices are the main driver for rent generation in the farming segment, whereas increased demand for goods and services is the most important driver for rent shifting. The increased demand originates from worsened biological farming conditions that force farmers to seek alternative operational measures to comply with strict regulations, e.g., mechanical delousing, genetically modified roe, post-smolt, etc. In line with economic theory, farming rent seems to persist in the long run due to capacity constraints, whereas new entrants and adaptation by existing players mitigate the long-run persistence of rent shifting.

Considering the continuously rising production costs in the farming segment, one could expect an even greater dependency on the fish price going forward. Technical advancements and biologically improved production conditions have the potential to increase supply in the long run and thus push prices down. However, the industry has a solid track record of extracting latent demand in excess of the supply growth, and there is no reason to believe that the full market potential is released any time soon. Based on the preceding reasoning, one should expect the normalized resource rent to remain positive in the foreseeable future.

The rent shifting effects have a strong reverting tendency because of forces in the competitive markets where the level of profits encourages changed behavior. There are clear signs of adaptation to increased demand where supply is rapidly building up in most of the profitable segments. For this reason, one should expect the future shifting effects to approach zero. However, the industry has yet to solve the existing biological issues that explain the increased demand. Thus, one cannot suppress the chances of new exogenous shocks in the future, e.g., new treatment methods, new regulations, etc. that could alter current demand and facilitate continuous shifting.

This thesis contributes to the literature on resource rent by providing a comprehensive bottom-up analysis of rent generation in the Norwegian aquaculture industry. Further, the study is, to the best of my knowledge, the first to empirically quantify rent shifting effects. Moreover, my results contribute with new insights into the ongoing debate on whether the industry generates rent and should be subject to special taxes by providing empirical evidence of rent.

Despite robust estimates, this study has at least three limitations. First, the methodology does not allow for a meaningful quantification of uncertainty contained in the estimates, such as confidence intervals. To obtain probabilities of statistical significance, one must have data on firm-level that accounts for ongoing consolidation and restructuring activity. Financial statements, as reported by individual entities, fail to adequately account for such activity within organizations because one firm may have assets, and another firm may have the associated income and costs during the restructuring process.

Second, my approach does not separate between different kinds of rent. As a result, it is highly likely that my empirical results contain quasi rent. Although this has the potential to exaggerate resource rent estimate, I still argue that without access to common property, there would not be any rent generation at all since the industry cannot operate without quality water and designated areas.

Finally, I do not consider any suboptimal firm or industry structures resulting from the coastal population politics of Norway, which possibly undermine the potential value of the resource by allowing the least efficient firms to continue its operations, i.e., the authorities may have different objectives than maximizing the value of the resources.

All the above limitations are interesting avenues for further research and could contribute greatly to our understanding of how policies affect the value of natural resources.

To conclude, the Norwegian aquaculture industry generates substantial resource rent from its privileged access to high-quality natural resources, and the question of who benefits from the common property is more relevant than ever.

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Appendices

Appendix 1 Codes for Industrial Classification

Codes represented in the data set – totaling 108 codes			
1280	25110	42210	52229
1500	25290	42990	52291
3111	25620	43210	52292
3211	25930	43221	58290
3212	25990	43330	62010
3213	26510	43990	62090
3222	26700	45200	68100
9109	27110	46120	68209
10201	27900	46389	70220
10202	28120	46460	71121
10209	28130	46473	71129
10411	28221	46510	71200
10890	28229	46610	72110
10910	28250	46620	72190
13929	28290	46630	72200
13940	28930	46691	73110
13950	28990	46692	74101
20110	30111	46693	74909
20140	30112	46694	77340
20300	30115	46739	77390
20590	30120	46740	78200
21200	33150	46750	80200
22210	33200	46769	81210
22220	35113	46900	85320
22230	38210	50201	85599
22290	41109	50202	85609
23140	41200	52222	86906

Appendix 2 Segment-based Profitability Analysis

This appendix reports key results from the segment-based profitability analysis on which I estimate the resource rent. I report a table with eight variables for each segment in addition to a graph to better visualize the historical development of key financial ratios. Further, I also report the five largest companies in each segment based on revenues in 2017.

Tables follow this basic structure:

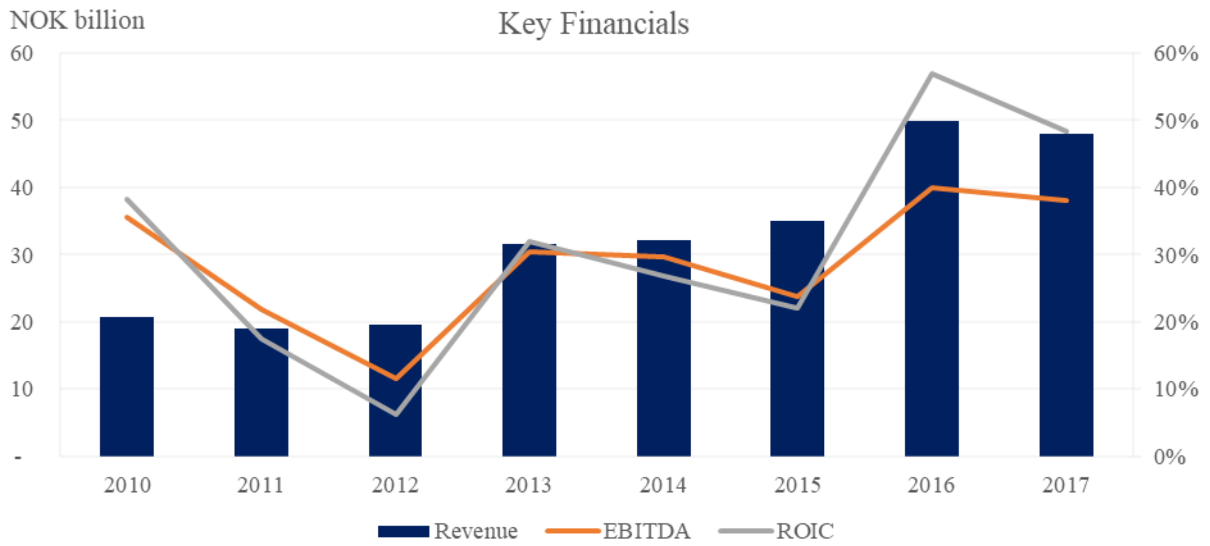
Variable	**Definition**
Number of Companies	Shows the number of companies in the respective fiscal year
WACC	See subchapter 4.3
ROE (Return on Equity)	$ROE_t = \frac{After\ tax\ profit_t}{(Equity_t + Equity_{t-1})/2}$
ROIC (Return on IC)	$ROIC_t = \frac{EBIT_t}{(IC_t + IC_{t-1})/2}$
Turnover	$Turnover_t = \frac{Revenue_t}{(IC_t + IC_{t-1})/2}$
Operating margin	$Operating\ margin_t = \frac{EBIT_t}{Revenue_t}$
EBITDA margin	$EBITDA\ margin_t = \frac{EBITDA_t}{Revenue_t}$
Credit Rating	See subchapter 4.3.2

The appendix is structured as follows: Farming (p.87), Roe (p.88), Smolt (p.89), Wellboats (p.90), Service Vessels (p.91), Feed Producers (p.92), Feed Carriers (p.93), Cleaner Fish (p.94), Equipment (p.95), Processing (p.96), Packaging (p.97), Fish Health (p.98), NSB-Equipment (p.99), Shipyards (p.100), and Other Services (p.101).

Farming

Largest Companies by Revenue 2017 (floating prices)

1.	2.	3.	4.	5.
Classified	Classified	Classified	Classified	Classified

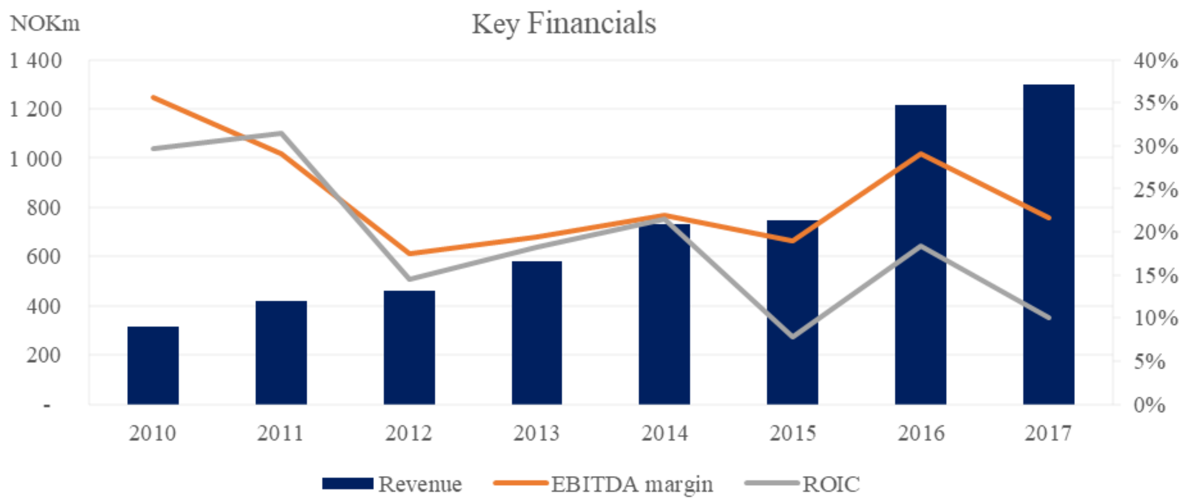


Variable	2010	2011	2012	2013	2014	2015	2016	2017
Number of Companies	101	92	94	91	88	88	84	82
WACC (%)	10.68	10.93	10.06	10.88	10.33	8.55	7.93	8.77
ROE (%)	0.00	21.69	7.18	45.53	35.03	27.00	55.39	43.42
ROIC (%)	38.33	17.49	6.18	32.01	26.76	22.09	56.88	48.28
Turnover	1.1823	0.9875	0.8753	1.1897	1.0308	1.1139	1.5556	1.4012
Operating margin (%)	32.42	17.71	7.07	26.91	25.96	19.84	36.57	34.45
EBITDA margin (%)	35.65	21.83	11.50	30.44	29.65	23.81	40.00	38.04
Credit Rating	A+	BBB	BB	BBB	BBB	BBB	A	A

Roe

Largest Companies by Revenue 2017 (floating prices)

1.	2.	3.	4.	5.
AquaGen	SalmoBreed	Nordnorsk Stamfisk AS	Salten Stamfisk	Svanøy Havbruk

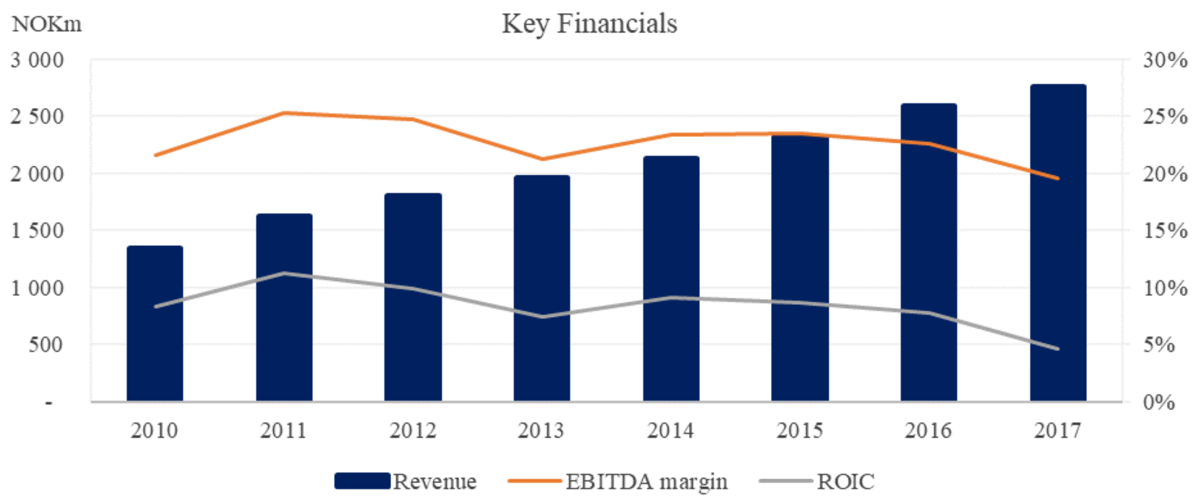


Variable	2010	2011	2012	2013	2014	2015	2016	2017
Number of Companies	8	8	9	9	9	10	11	12
WACC (%)	10.83	10.68	9.89	10.61	10.07	8.61	8.07	8.87
ROE (%)	24.32	18.79	13.18	16.42	22.81	15.02	28.47	17.12
ROIC (%)	35.46	39.75	19.86	22.99	28.17	12.01	23.05	13.35
Turnover	1.1364	1.5617	1.4735	1.4753	1.5168	0.8710	0.9451	0.8251
Operating margin (%)	31.20	25.45	13.48	15.58	18.57	13.78	24.39	16.18
EBITDA margin (%)	35.65	29.01	17.51	19.34	21.98	18.98	29.15	21.62
Credit Rating	A+	A	BBB	A	A-	A-	A	A

Smolt

Largest Companies by Revenue 2017 (floating prices)

1. SalMar (Settefisk)
2. Nordlaks (Smolt)
3. Lerøy (Laksefjord)
4. Helgeland Smolt
5. AS Sævareid Fiskeanlegg

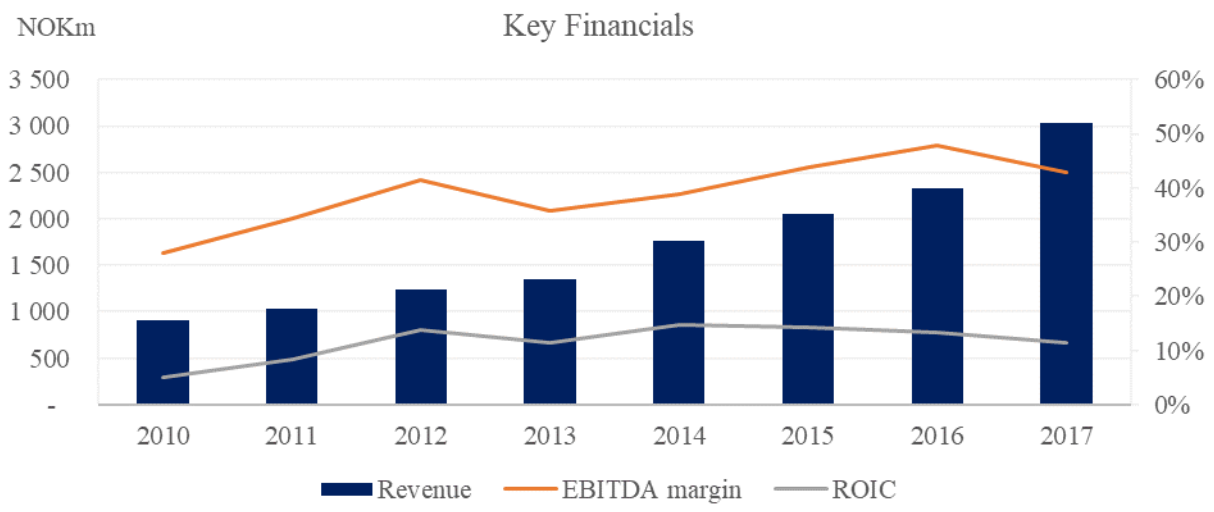


Variable	2010	2011	2012	2013	2014	2015	2016	2017
Number of Companies	70	73	73	74	75	77	79	83
WACC (%)	10.75	12.13	10.11	11.56	11.36	9.73	9.71	9.96
ROE (%)	12.23	15.10	12.08	10.22	12.03	12.12	14.74	9.52
ROIC (%)	8.28	11.25	9.90	7.46	9.07	8.62	7.78	4.64
Turnover	0.6394	0.7014	0.6865	0.6842	0.6796	0.6631	0.6297	0.5326
Operating margin (%)	12.95	16.04	14.43	10.90	13.35	13.00	12.35	8.72
EBITDA margin (%)	21.56	25.34	24.69	21.27	23.33	23.48	22.64	19.57
Credit Rating	BBB	BB+	BBB	BB+	BB	BB	BB	BB

Wellboats

Largest Companies by Revenue 2017 (floating prices)

1. ROSTEIN AS
2. SØLVTRANS
3. NFT NORSK FISKETRANSPORT AS
4. FRØY (Rederi)
5. OPPDRETTERNES MILJØSERVICE AS

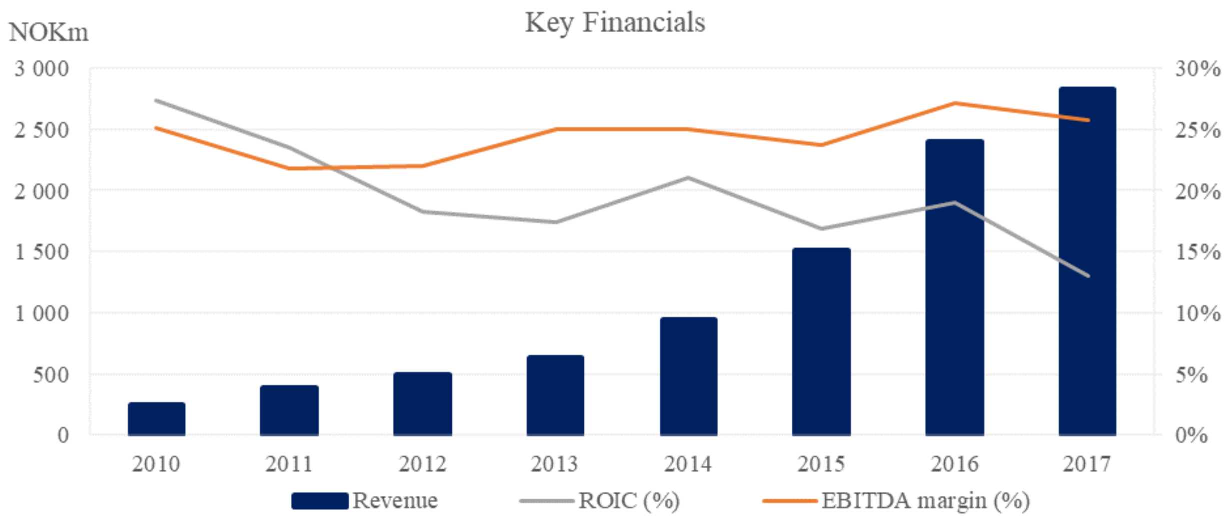


Variable	2010	2011	2012	2013	2014	2015	2016	2017
Number of Companies	18	20	21	23	22	25	26	27
WACC (%)	12.77	12.24	12.01	11.73	10.45	9.16	8.96	10.04
ROE (%)	-1.43	9.10	31.50	23.46	27.82	32.91	32.03	25.08
ROIC (%)	5.14	8.32	13.90	11.35	14.69	14.26	13.23	11.51
Turnover	0.4425	0.4793	0.5312	0.4901	0.5119	0.4315	0.3696	0.3880
Operating margin (%)	11.61	17.36	26.16	23.17	28.71	33.05	35.78	29.67
EBITDA margin (%)	28.07	34.32	41.60	35.89	39.00	43.82	47.77	42.97
Credit Rating	B+	BB	BB+	BB+	BBB	BBB	BBB	BB+

Service Vessels

Largest Companies by Revenue 2017 (floating prices)

1. FRØY (Akvaservice)
2. AQS Maritim Presisjon
3. FRØY (Vest)
4. abyss
5. AKVA GROUP Marine Services

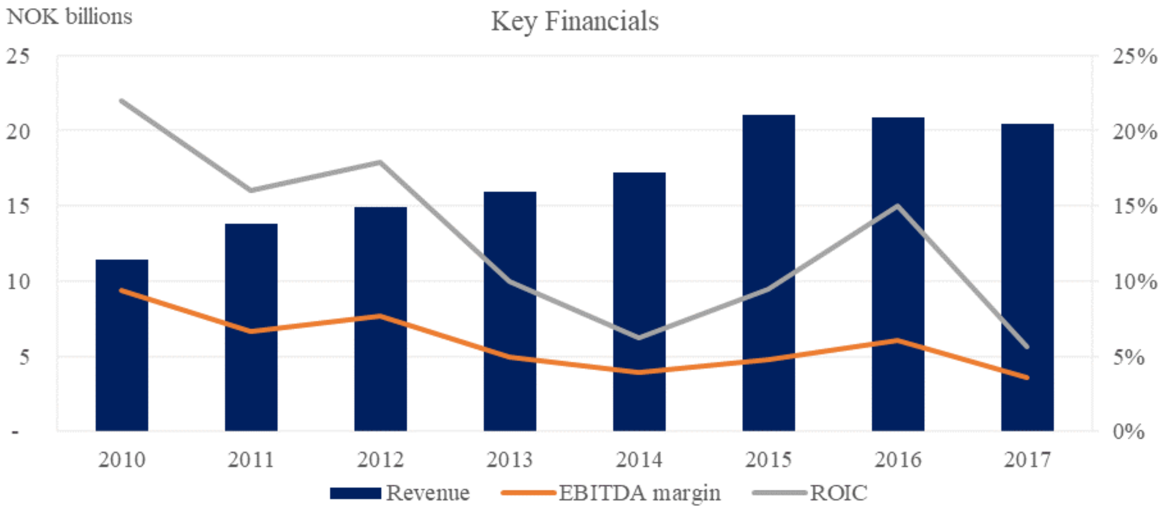


Variable	2010	2011	2012	2013	2014	2015	2016	2017
Number of Companies	27	32	37	44	51	67	81	86
WACC (%)	10.75	10.98	11.93	11.71	11.19	9.96	8.95	9.39
ROE (%)	29.79	25.64	23.79	24.69	35.37	33.08	40.82	24.90
ROIC (%)	27.38	23.49	18.29	17.47	21.08	16.91	19.02	13.00
Turnover	1.7442	1.8243	1.4625	1.2307	1.2356	1.1362	1.1032	0.9448
Operating margin (%)	15.70	12.88	12.51	14.19	17.06	14.88	17.24	13.76
EBITDA margin (%)	25.15	21.84	22.07	25.07	25.04	23.73	27.13	25.78
Credit Rating	BBB	BBB	BB+	BB+	BB+	BB+	BBB	BBB

Feed Producers

Largest Companies by Revenue 2017 (floating prices)

1. SKRETTING
2. BioMar
3. EWOS
4. MOWI
5. ALLER AQUA

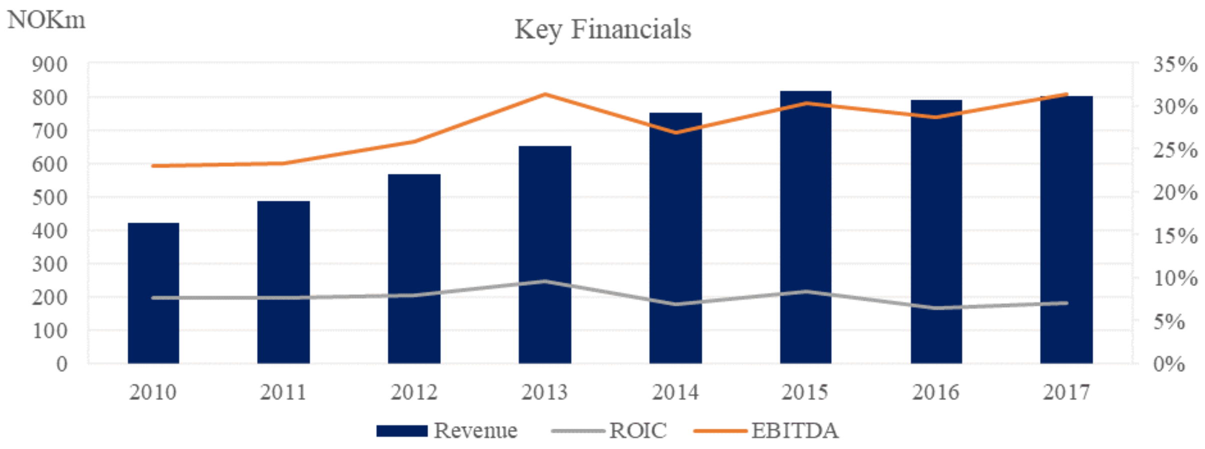


Variable	2010	2011	2012	2013	2014	2015	2016	2017
Number of Companies	6	7	7	8	7	9	9	9
WACC (%)	10.76	10.94	10.03	11.30	11.38	8.85	7.85	8.84
ROE (%)	31.59	16.47	24.95	8.23	6.12	8.44	11.07	11.60
ROIC (%)	22.02	16.05	17.94	9.98	6.27	9.46	15.06	5.66
Turnover	2.8761	3.1544	2.9798	2.9933	2.9764	3.4696	3.5024	3.3340
Operating margin (%)	7.66	5.09	6.02	3.33	2.10	2.73	4.30	1.70
EBITDA margin (%)	9.43	6.69	7.67	4.98	3.94	4.77	6.07	3.62
Credit Rating	BBB	BBB	BBB	BB+	B+	BB	BBB	BB

Feed Carriers

Largest Companies by Revenue 2017 (floating prices)

1. Eidsvaag
2. Egil Ulvan Rederi AS
3. AquaShip Feedtrans AS
4. Bio Feeder AS
5. EIDSHAUG REDERI AS



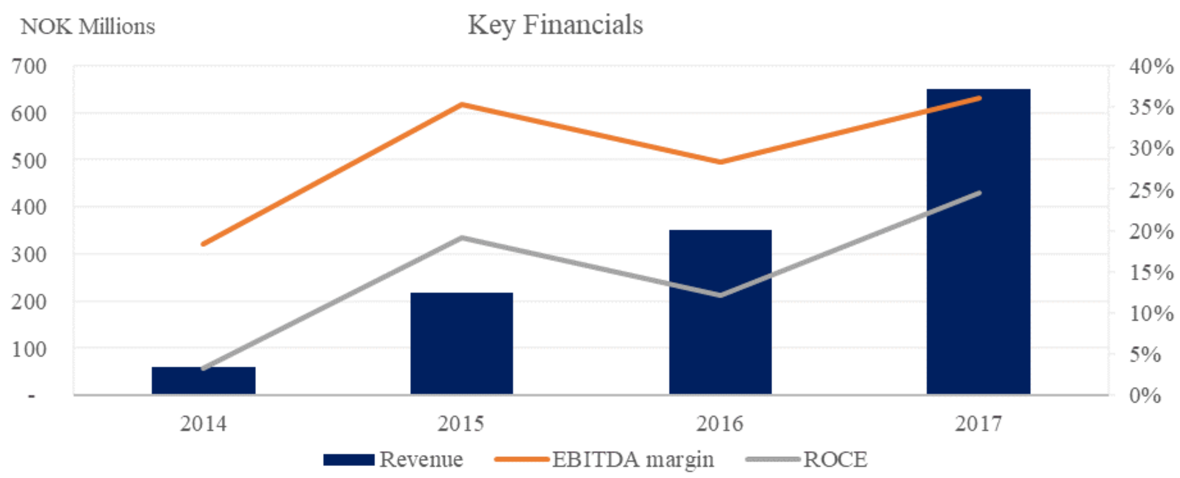
Variable	2010	2011	2012	2013	2014	2015	2016	2017
Number of Companies	10	10	10	10	10	10	10	10
WACC (%)	12.03	12.24	12.56	11.87	11.38	9.96	9.79	10.12
ROE (%)	10.87	14.26	14.27	17.25	12.89	20.44	15.99	14.39
ROIC (%)	7.65	7.70	8.02	9.68	6.93	8.42	6.47	7.01
Turnover	0.6177	0.6187	0.5834	0.5218	0.4831	0.4985	0.4498	0.4020
Operating margin (%)	12.38	12.45	13.74	18.56	14.34	16.89	14.38	17.43
EBITDA margin (%)	23.12	23.39	25.91	31.45	26.90	30.43	28.66	31.45
Credit Rating	BB+	BB	BB	BB+	BB+	BB+	BB+	BB+

Cleaner Fish

Largest Companies by Revenue 2017 (floating prices)

1. 2. 3. 4. 5.

Senja Akvakultursenter AS

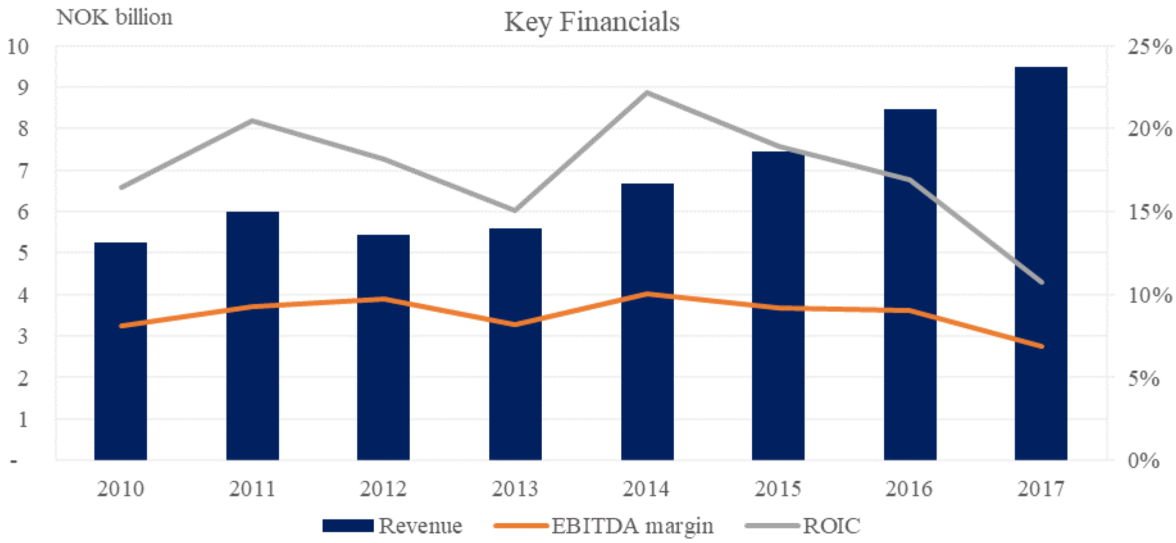


Variable	2010	2011	2012	2013	2014	2015	2016	2017
Number of Companies	-	-	-	-	14	22	23	25
WACC (%)	-	-	-	-	17.87	12.10	10.90	9.90
ROE (%)	-	-	-	-	39.80	77.95	26.86	49.26
ROIC (%)	-	-	-	-	6.76	39.01	17.93	32.00
Turnover	-	-	-	-	1.1354	1.3590	0.9092	1.1111
Operating margin (%)	-	-	-	-	5.96	28.71	19.72	28.80
EBITDA margin (%)	-	-	-	-	18.36	35.29	28.39	36.15
Credit Rating	-	-	-	-	CC	CCC	B+	BB

Equipment

Largest Companies by Revenue 2017

1. OPTIMAR
2. AKVA GROUP
3. STEINSVIK
4. aqualine
5. Egersund Net

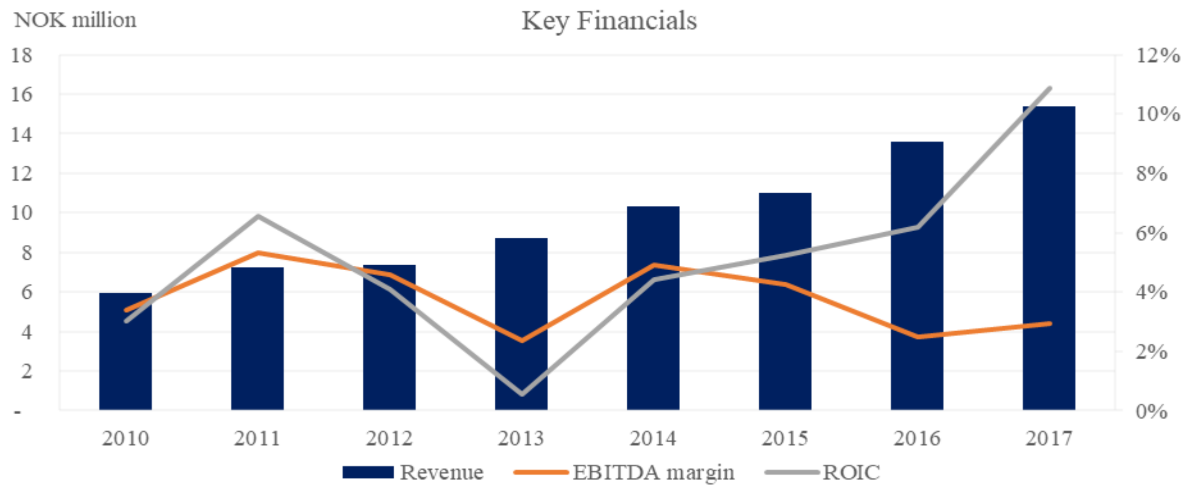


Variable	2010	2011	2012	2013	2014	2015	2016	2017
Number of Companies	74	76	83	85	85	94	99	103
WACC (%)	10.80	10.90	10.00	10.83	10.28	8.79	8.44	9.10
ROE (%)	15.22	17.76	15.42	11.65	18.85	14.75	14.75	9.24
ROIC (%)	16.48	20.49	18.17	15.08	22.18	18.92	16.92	10.73
Turnover	2.8026	2.9269	2.4966	2.5572	2.7651	2.6629	2.4580	2.2532
Operating margin (%)	5.88	7.00	7.28	5.90	8.02	7.11	6.88	4.76
EBITDA margin (%)	8.15	9.27	9.71	8.17	10.03	9.19	9.06	6.86
Credit Rating	BBB	BBB	BBB	BBB	BBB	BBB	BBB	BBB

Processing

Largest Companies by Revenue 2017 (floating prices)

1.	2.	3.	4.	5.
Sekkingstad	HOFSETH	NILS WILLIKSEN	Norsk Sjømat As Quality Seafood	nordlaks (Produkter)

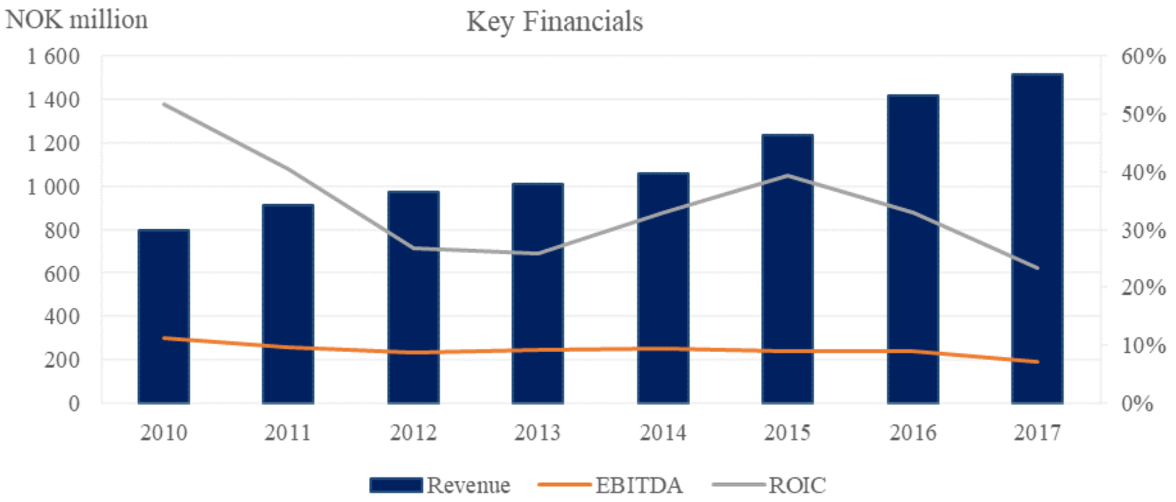


Variable	2010	2011	2012	2013	2014	2015	2016	2017
Number of Companies	43	46	47	48	50	55	56	55
WACC (%)	14.60	13.42	14.66	15.94	15.31	11.71	11.83	11.07
ROE (%)	22.81	27.25	17.37	-22.19	11.58	8.04	9.92	6.26
ROIC (%)	3.02	6.57	4.10	0.57	4.41	5.23	6.19	10.87
Turnover	1.6708	1.7580	1.4408	1.3866	1.3120	1.9646	5.4122	6.4600
Operating margin (%)	1.81	3.74	2.85	0.41	3.36	2.66	1.14	1.68
EBITDA margin (%)	3.40	5.31	4.56	2.37	4.90	4.24	2.50	2.93
Credit Rating	B	B+	B	B-	B-	B-	B-	B-

Packaging

Largest Companies by Revenue 2017 (floating prices)

1. VARTDAL PLAST
2. BEWi
3. nesseplast
4. accon
5. STRØMBERGS

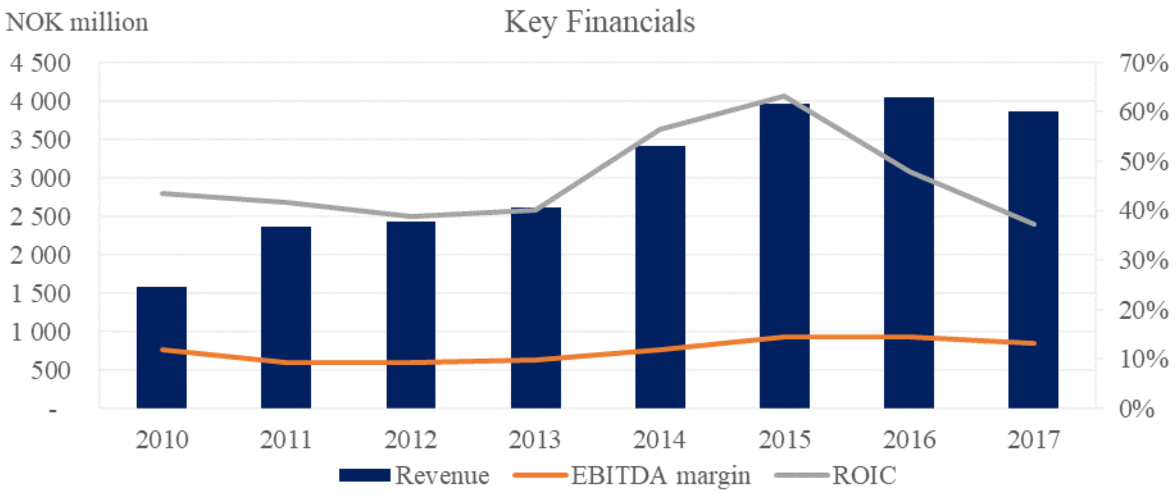


Variable	2010	2011	2012	2013	2014	2015	2016	2017
Number of Companies	6	6	8	8	9	9	9	9
WACC (%)	10.74	10.60	9.79	10.59	10.05	8.46	7.85	8.82
ROE (%)	27.21	25.19	19.79	22.08	23.30	25.30	23.36	17.71
ROIC (%)	51.76	40.52	26.78	25.88	33.09	39.35	32.92	23.46
Turnover	5.6651	5.4313	4.2953	3.8003	4.6144	5.6463	5.1549	4.6299
Operating margin (%)	9.14	7.46	6.23	6.81	7.17	6.97	6.39	5.07
EBITDA margin (%)	11.21	9.67	8.66	9.26	9.47	9.09	8.89	7.22
Credit Rating	A	A	A	A	A	A	A+	A

Fish Health

Largest Companies by Revenue 2017 (floating prices)

1. PHARMAQ
2. Europharma
3. Nofima
4. VESO
5. MSD Animal Health

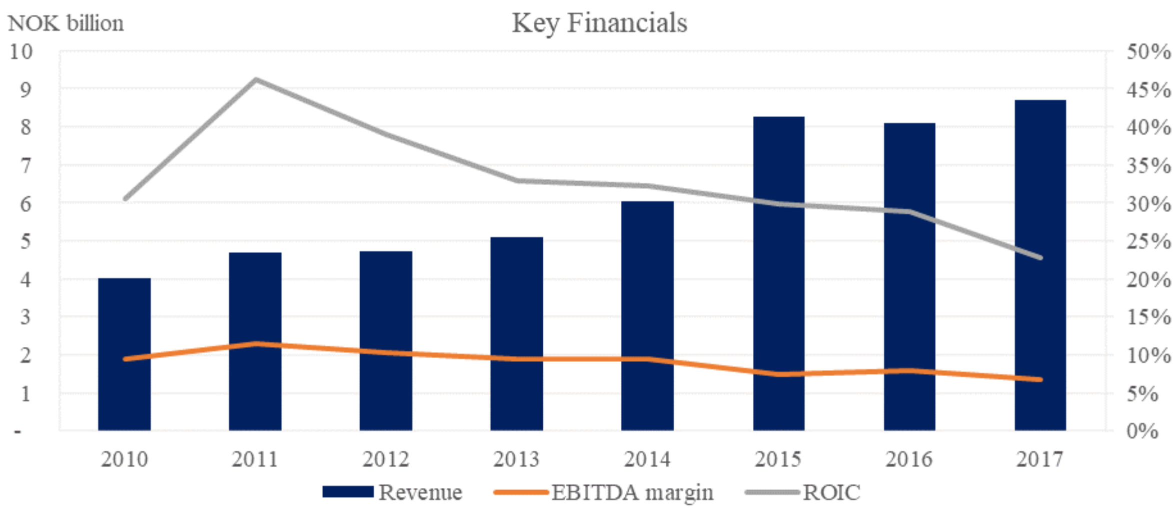


Variable	2010	2011	2012	2013	2014	2015	2016	2017
Number of Companies	27	30	32	33	35	35	39	39
WACC (%)	10.78	10.61	9.79	10.58	10.04	8.63	8.39	8.86
ROE (%)	40.32	45.15	42.89	48.15	56.52	72.20	51.80	36.21
ROIC (%)	43.51	41.63	38.81	40.24	56.38	63.22	47.82	37.17
Turnover	4.1108	5.4759	4.9401	4.8249	5.4397	4.8802	3.7930	3.3753
Operating margin (%)	10.58	7.60	7.86	8.34	10.36	12.95	12.61	11.01
EBITDA margin (%)	11.90	9.23	9.39	9.89	11.93	14.54	14.46	13.05
Credit Rating	BBB	A-	A	A	A	A-	A-	A

Non-sea-based Equipment

Largest Companies by Revenue 2017 (floating prices)

1. 2. 3. 4. 5.

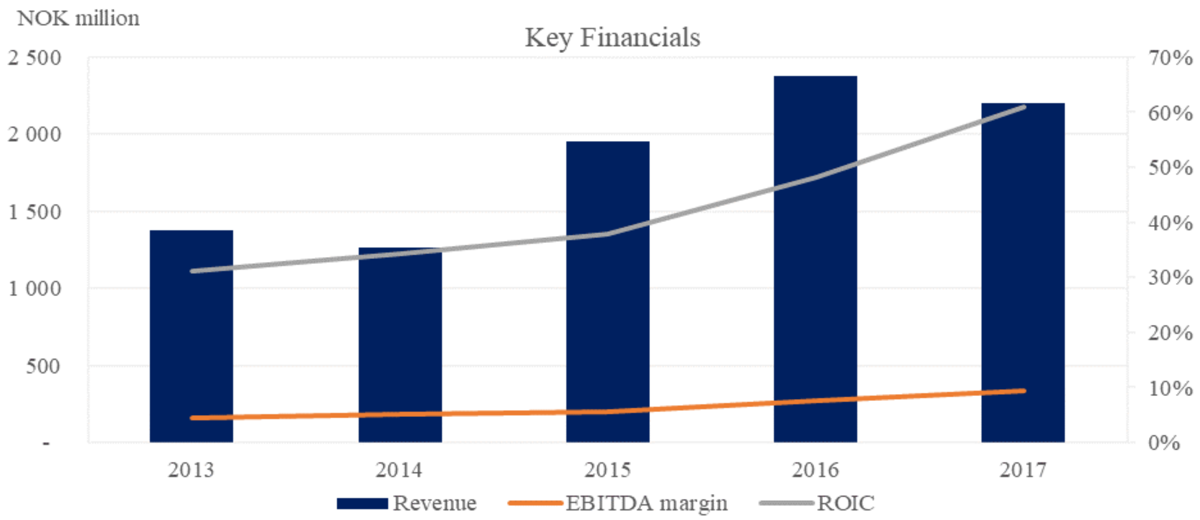


Variable	2010	2011	2012	2013	2014	2015	2016	2017
Number of Companies	54	57	58	61	64	68	69	71
WACC (%)	9.35	8.56	7.89	8.44	8.30	7.34	7.22	9.16
ROE (%)	31.83	46.34	37.28	35.81	41.75	33.07	25.68	17.61
ROIC (%)	30.61	46.17	38.98	32.98	32.21	29.96	28.82	22.80
Turnover	4.2427	4.8781	4.6207	4.2906	4.2574	5.2663	4.8620	4.6550
Operating margin (%)	7.21	9.47	8.44	7.69	7.56	5.69	5.93	4.90
EBITDA margin (%)	9.41	11.45	10.37	9.54	9.49	7.52	8.01	6.80
Credit Rating	BBB	A-	BBB	BBB	BB+	BBB	BBB	BB

Shipyards

Largest Companies by Revenue 2017 (floating prices)

1. 2. 3. 4. 5.

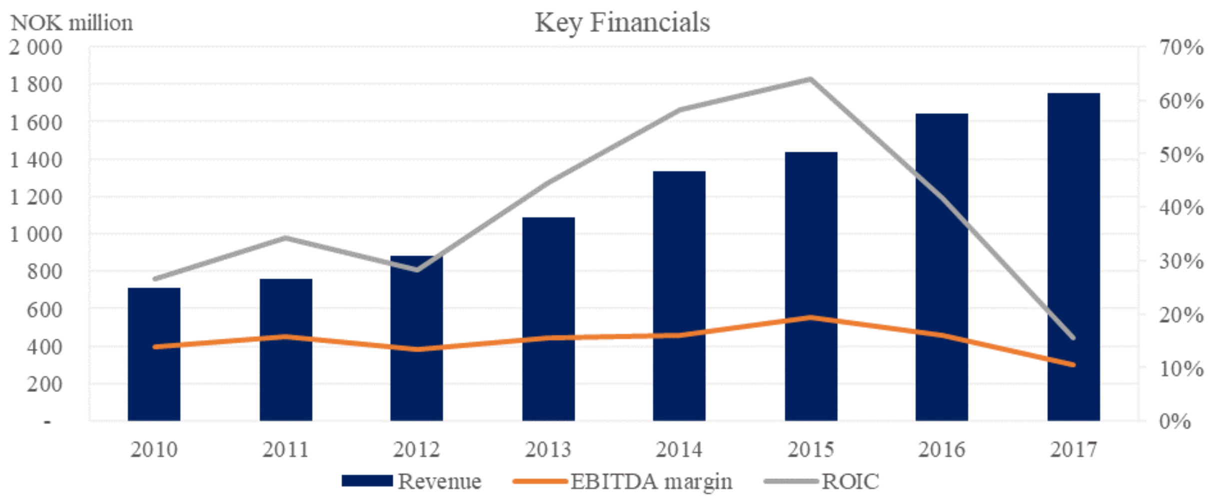


Variable	2010	2011	2012	2013	2014	2015	2016	2017
Number of Companies	-	-	-	18	19	20	21	21
WACC (%)	-	-	-	11.00	10.34	7.98	6.83	7.24
ROE (%)	-	-	-	12.78	13.36	20.20	35.40	43.62
ROIC (%)	-	-	-	31.27	34.30	37.95	48.31	60.91
Turnover	-	-	-	7.9783	7.6907	7.6542	7.0129	7.1109
Operating margin (%)	-	-	-	3.92	4.46	4.96	6.89	8.57
EBITDA margin (%)	-	-	-	4.59	5.24	5.53	7.53	9.32
Credit Rating	-	-	-	BBB	BBB	BBB	BBB	A-

Other Services

Largest Companies by Revenue 2017 (floating prices)

1. ØPD
2. ARGON ELEKTRO MARITIM
3. A-R Akva-Ren AS
4. Kolos
5. NOFI Oppdrettservice AS



Variable	2010	2011	2012	2013	2014	2015	2016	2017
Number of Companies	20	21	29	30	31	36	40	43
WACC (%)	10.00	10.30	9.15	10.63	10.20	8.26	7.31	7.88
ROE (%)	21.69	27.05	20.21	33.65	42.72	43.49	36.12	11.90
ROIC (%)	26.69	34.19	28.19	44.49	58.30	63.91	41.79	15.54
Turnover	3.1048	3.1881	3.2618	3.8803	4.8264	4.1537	3.6619	3.0235
Operating margin (%)	8.60	10.72	8.64	11.47	12.08	15.39	11.41	5.14
EBITDA margin (%)	13.90	15.84	13.42	15.59	15.97	19.50	16.16	10.65
Credit Rating	BBB	BBB	BBB	BBB	BBB	A-	A	BBB

Appendix 3 License Value

I estimate the value of a license by calculating the present value of expected future resource rents in perpetuity.

	2010	2011	2012	2013	2014	2015	2016	2017
rf_t	8.64	1.99	-1.25	6.97	6.22	5.02	18.50	16.81
Weight	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2

Notes: See chapter 6 Table 6 for the resource rent estimates. I assume a higher weight on the two most recent years from a behavioral standpoint. I find it reasonable that recent prosperity has a somewhat more significant impact on present investment behavior compared to older years. Additionally, I assume a concave utility function of money.

Calculate in perpetuity with the following assumptions:

Weighted average annual resource rent in NOK/kg	9.821
WACC	10 %
Economic growth	2 %
Size of a License in tonnes	780
Production per license in tonnes*	1,140

Notes: *the average quantity of sold fish per license during 2010-2017 in GWE tonnes (DoF, 2018a).

The value of a license is then:

$$V_L = \frac{9.821 * 1{,}140 * 1000}{0{,}1 - 0{,}02} = 139{,}949{,}250$$

$$V_l = \frac{139{,}949{,}250}{780} = 179{,}422.12$$

Where V_L is the total value of a license in NOK, and V_l is the value of a license in NOK per tonne.