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Economic rents in Norwegian aquaculture

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Summary

This report is a summary of the findings in from the project "NFR 283312 – FISH TAX: Resource rent and taxation in the Norwegian Fisheries and Aquaculture industries" funded by the Norwegian Research Council SKATT programme. The report consists of three separate papers:
Paper 1 "Aquaculture license auctions and inframarginal rents in salmon aquaculture"
Paper 2 "Sustainable growth, resource rent and taxes in aquaculture"
Paper 3 "Economic rents in salmon aquaculture"

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1. Overview of report

This report is a summary of the findings in from the project “NFR 283312 – FISH TAX: Resource rent and taxation in the Norwegian Fisheries and Aquaculture industries” funded by the Norwegian Research Council SKATT programme. The report consists of three separate papers:

Paper 1 “Aquaculture license auctions and inframarginal rents in salmon aquaculture”

Paper 2 “Sustainable growth, resource rent and taxes in aquaculture”

Paper 3 “Economic rents in salmon aquaculture”

Below are the summaries of the three papers:

Paper 1 “Aquaculture license auctions and inframarginal rents in salmon aquaculture”

Substantial increases in profitability, in both fisheries and aquaculture, in the recent years have prompted increased attention to rent creation and rent capture in the seafood sector. In fact, Iceland, The Faroe Island and Norway have all recently implemented taxation of economic rent from salmon aquaculture. Estimation of economic rent is challenging for many reasons, particularly due to its elusive nature and widespread confusion amongst academics as to how to identify and quantify different sources of economic rent. Moreover, accurate rent estimations require that inframarginal profits are not ignored but estimated alongside rent. Ignoring inframarginal profits will overestimate economic rents, which could be problematic since in some industries inframarginal profits can be substantial. We find that salmon aquaculture is one of these. Using data on auction of salmon production capacity from 2018 and 2020, we estimate the market values of salmon farming licenses include a substantial value from inframarginal profits. We find that companies that are less efficient have a larger willingness to pay for marginal production capacity than larger salmon farming companies do, suggesting that inframarginal profits are important in explaining the variation in willingness to pay for new production capacity.

Paper 2 "Sustainable growth, resource rent and taxes in aquaculture"

Global aquaculture represents an opportunity for sustainable growth in supply of healthy food and private and public income, but also has environmental footprints and thus requires a balanced policy approach by governments. Salmon aquaculture has until recently experienced rapid growth, and periods of high profitability. In all producer countries, salmon aquaculture is subject to different regulations that indirectly restrict output at the firm level and may restrict global supply in the short run. The sector has become a candidate for extraordinary taxation in Norway, and a tax regime which is unique in the context of global food production is under consideration. An argument is that society allocates sea locations to salmon firms for free, and that these provide economic returns well above normal returns to capital due to the number of sites being limited, both in Norway and globally. This paper uses a panel data set to analyze patterns of productive performance and profitability in Norwegian salmon aquaculture to analyze whether these patters suggest economic rents or inframarginal profits. We find significant variations in productive and economic performance over time and across firms, a variability that is inconsistent with a claim that all the economic profits are a resource rent generated by a natural resource in the form of limited aquaculture sites. Our results suggest that inframarginal profits are important part of total profits in the salmon aquaculture sector.

Paper 3 "Economic rents in salmon aquaculture"

In recent years, the Norwegian salmon aquaculture industry has generated substantial extraordinary profits, and market values of farming licences have soared, suggesting that the industry is generating substantial economic rents. Yet very little is known about the nature of economic rents created in salmon aquaculture. The rents may be a manifestation of scarce resources, such as limited access to suitable production sites or farming licences. Alternatively, there could be regulation rents due to environmental regulation, or possibly persistent inframarginal rents due to heterogeneity in skills and efficiencies amongst producers. The purpose of this paper is two-fold. First, we examine the nature of economic rents in Norwegian salmon aquaculture, and in the second part we estimate the size of the rents. Our analysis suggests that economic rents in salmon aquaculture since 2013 are likely to be in the form of environmental regulation rent, as well as inframarginal and quasi rents, rather than classical scarcity or resource rents. In the last 10–20 years, the motivation for regulation has shifted from fear of overproduction and subsequent dumping and subsidy allegations to motivation grounded in environmental and biohazard concerns. Combined with demand growth, imperfect environmental regulation can result in an environmental regulation rent. We estimate the size and time variation of total, inframarginal and regulation rents using data from Norwegian salmon farmers from 2000 to 2020. Until 2013, the economic rent was cyclical in nature, alternating between periods of positive and negative (?) rents. Since 2013, however, economic rent has increased substantially, coinciding with more stringent environmental regulation. In recent years, the regulation rent has dissipated, and partially been replaced by increased inframarginal rent. The latter a result of increased cost heterogeneity, partly explained by more stringent environmental regulation and increased sea lice treatment costs. Our study contributes to an increasing literature in fisheries and aquaculture on inframarginal rents and increases our knowledge on rent generation and dissipation in salmon aquaculture.

2. Paper 1 «Aquaculture license auctions and inframarginal rents in salmon aquaculture»

2.1. Abstract

Substantial increases in profitability, in both fisheries and aquaculture, in the recent years have prompted increased attention to rent creation and rent capture in the seafood sector. In fact, Iceland, The Faroe Island and Norway have all recently implemented taxation of economic rent from salmon aquaculture. Estimation of economic rent is challenging for many reasons, particularly due to its elusive nature and widespread confusion amongst academics as to how to identify and quantify different sources of economic rent. Moreover, accurate rent estimations require that inframarginal profits are not ignored but estimated alongside rent. Ignoring inframarginal profits will overestimate economic rents, which could be problematic since in some industries inframarginal profits can be substantial. We find that salmon aquaculture is one of these. Using data on auction of salmon production capacity from 2018 and 2020, we estimate the market values of salmon farming licenses include a substantial value from inframarginal profits. We find that companies that are less efficient have a larger willingness to pay for marginal production capacity than larger salmon farming companies do, suggesting that inframarginal profits are important in explaining the variation in willingness to pay for new production capacity.

2.2. Introduction

The topic of profits and rents in resource industries, such as fisheries, has resulted in numerous academic articles on rent creation, dissipation and capture for many decades (Warming, 1911; Gordon, 1954; Smith, 1969; Christy, 1973; Wilen, 1976; Bjørndal and Conrad, 1987; Flaaten et al., 1995; Newell et al., 2005; Costello et al., 2008; Asche et al., 2009; Lian et al., 2009; Deacon et al., 2011; Grafton, 1992, 1994, 1995, 1996; Johnson, 1995; Matthiasson, 2008; Flaaten and Schultz, 2010). The topic of rent capture (e.g. by taxation) has in recent years been motivated by increased profitability both in the fisheries and aquaculture sectors. Both industries have increasingly become candidates for economic rent taxation. In fact, Iceland, the Faeroe Islands, and Norway have all either implemented or considering implementing models for rent capture from the salmon aquaculture industry. Iceland is considering and the Faeroes have implemented royalty taxation on the quantity of farmed salmon, while Norway has implemented a combination of a royalty tax (from 2022) and payment for aquaculture licenses (fixed fee from 2002, and auctions from 2018). Payment for aquaculture licenses is a form of rent taxation.

An important prerequisite for appropriate rent capture, is the process of identifying, and more importantly, quantifying the levels of rent (i.e. the tax base). While the fisheries literature on rent is vast, very few studies have examined rent in aquaculture.

Over the last 7–8 years, salmon aquaculture has generated high extraordinary profits (Figure 1).

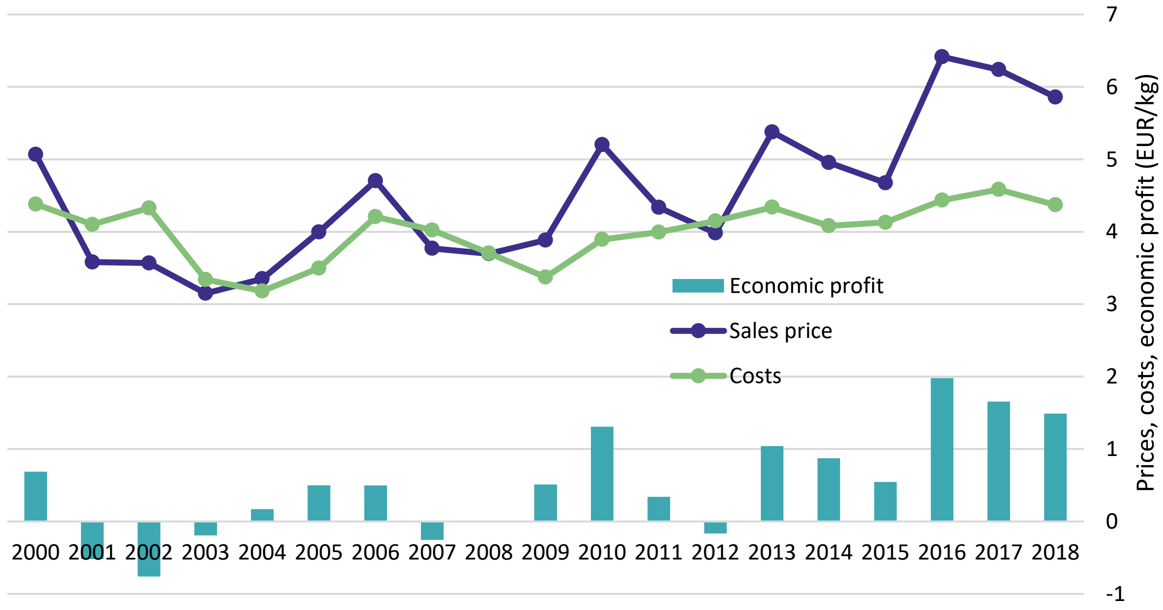

Figure 1. Prices, production costs and operating profit per kilo in Norwegian salmon aquaculture, in real EUR/kilo head-on gutted weight (2018=100). Sources: Norwegian Directorate of Fisheries and Aquaculture (survey data for prices and costs, and book value of assets from Atlantic salmon and rainbow trout farming firms), Statistics Norway (annual average consumer price index) and the Norwegian Central Bank (average annual Norwegian Kroner – Euro exchange rates), and own calculations. Economic profit is calculated as revenues less labour and operating costs, and minus capital costs. The latter are calculated from the book value of total assets less a cost of capital of 10%.

Figure 1 shows that Norwegian salmon aquaculture firms' economic profits typically follow a cyclical pattern (Asche and Sikveland, 2015). Since 2016, however, the profits have been at extraordinary high levels compared to previous years (Asche, Sikveland and Zhang, 2018; Misund and Nygård, 2018). There could many reasons for this. Although demand has demonstrated strong growth, albeit in an erratic pattern, (Asche et al., 2011; Brækkan and Thyholdt, 2014; Brækkan et al., 2018), production growth has stagnated (Figure 2). From the commercial breakthrough in the early 1970s to 2010, the production of farmed Norwegian salmon grew at around 18% per year. Since 2010, the growth rate has been around 4% on average per year.

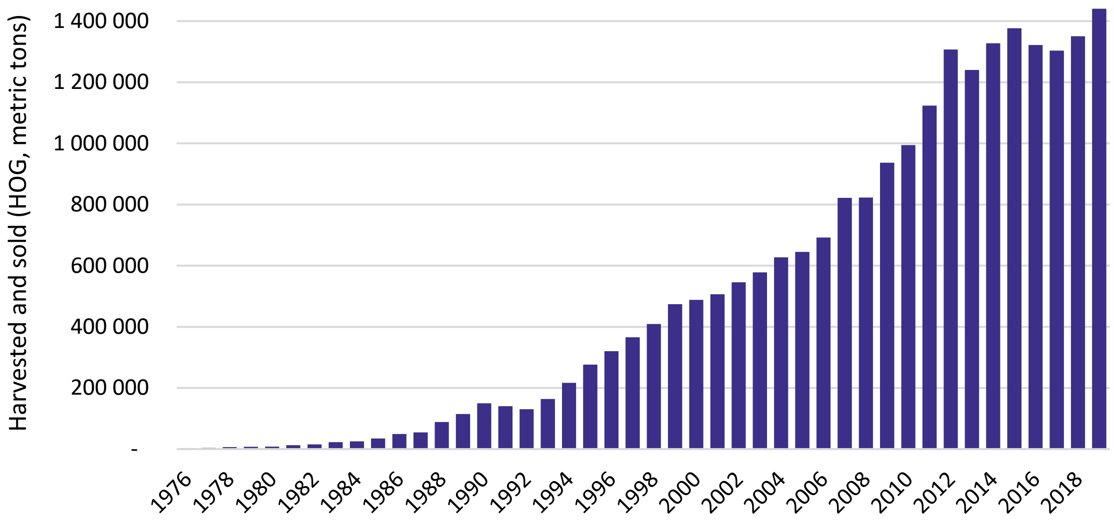

Figure 2. Production of salmon in Norway (metric tons, head-on gutted weight). Source: Statistics Norway.

There are several reasons for the substantial fall in production growth rates. Since the early 2000s productivity growth has fallen (Vassdal and Holst, 2011; Asche, Guttormsen and Nielsen, 2013; Rocha Aponte and Tveterås, 2019, Rocha Aponte, 2020). During the 1980s and 1990s, there was a substantial productivity growth due to innovations in fish health, nutrition and technology (Asche, Guttormsen and Tveterås, Tveterås, 1999; 2002; Tveterås and Heshmati, 2002; Asche, Roll and Tveterås, 2007; 2016; Roll, 2013). Furthermore, in 2005 the government put a cap on how much biomass the salmon farmers could have in their sea pens. Before 2005, firms could steadily increase production year by year by using larger and deeper sea pens since the regulation put a cap on sea pen volume down to a certain sea depth level, creating incentives for deeper sea pens.

Although production and demand has shown a substantial growth historically, salmon farmers have met challenges due to disease outbreaks, parasitic sea lice infestations, and escapees (Costello, 2009; Torrissen et al., 2011; Asche et al., 2013; Abolofia, Asche and Wilen, 2017). From the late 2000s environmental concerns have become more and more important. Biologists and environmental NGOs have raised concerns about the impact of salmon aquaculture on the welfare and survival of wild salmonids, as well as pollution of effluents and chemicals. In the late 200s the government started working on new regulation, aimed at taking into impact on wild salmonids. This work culminated in the traffic light system, implemented in 2017, allows for a 6 percent bi-annual production growth in geographical areas with low impact of sea lice on wild salmonids. It is here important to point out the regulation of production growth is based on concerns of a potential negative effect of salmon farming. There is an abundant literature on the negative impact of salmon lice and escapees in the survival and well-being of wild salmonids. However, the extent of the negative impact is as of yet unquantified.

Since production growth is regulated, salmon aquaculture is not a perfect competition market, and production levels are lower than they would be if production was unconstrained. Consequently, part of the extraordinary profits seen in recent years could be a form of economic rent. While accounting profits are readily available through aquaculture firm's financial statements, quantifying economic rent is very challenging for many reasons. Firstly, economic rent is a latent variable, and quantifying rents must be done by applying economic models. Secondly, there is much confusion in the literature on definition of rents, types of rents, and especially how to quantify them (Arnarson, 2011; Arnarson et al., 2018; Arnarson and Bjorndal, 2020).

The fisheries literature suggest that total variable profits is a combination of economic rents and infra-marginal profits (Arnarson et al., 2018). Inframarginal profits are generated from different efficiencies of firms, and of diminishing marginal productivity of the factors of production. In aquaculture, an example of the latter is marginal productivity at different production sites (geographical locations) (Arnarson & Bjorndal, 2020). In addition, there is economic rent, which can be higher or lower than total profits, but in normal circumstances with concave production functions, rent is lower than total profits. However, the content of the concept of economic rent can be quite elusive. Often, economic rent in fisheries will be referred to as resources rent, arising from access to a resource in limited supply. According to this view, economic rents in fisheries, and other similar resource industries, is a scarcity rent arising from a scarce resource, e.g. resource rents.

Another view is that the economic rent from fisheries is a regulatory rent (or management rent). Output from fisheries resources are typically restricted (regulated) to avoid the tragedy of the commons, giving rise to a management or regulatory rent.

Identifying specific types of rents is very challenging, as Arnarson et al. (2018) point out "*both rents and intra-marginal profits depend on the harvest level, the size of the resource (fish stocks) and the various other variables affecting the profit function. Therefore, it is misleading to attribute these two measures to one of these variables only. In particular, the rents are not solely generated by the resource. Some amount of the resource is of course necessary for rents, but it is by no means sufficient and the actual size of the rents depends on many other variables, including the harvest level, prices, the technology in use and the efficiency of the harvesting activity. Thus, attributing these rents to the resource only is misleading*".

Hence, identifying and quantifying specific types of rents is a daunting task, fraught with potential measurement errors. This is also the case in salmon aquaculture. As suggested above, high extraordinary profits indicate high levels of economic rents, but the sources of the rents are elusive. Not at least separating economic rent from inframarginal profit will be empirically quite challenging.

Recently, some researchers have tried to quantify resource and regulatory rents in Norwegian aquaculture (Flaaten & Tham, 2019), but their approach has been critized by Arnarson & Bjorndal (2020) on the grounds that Flaaten & Tham's approach did not take into account inframarginal profits, which could be substantial.

Our paper tries to address this conundrum. We seek to identify inframarginal profits by using a different approach compared to other studies. If economic rents in salmon aquaculture comes in the form of a regulatory rent, then arguably this rent should be equal across companies. Any variation in profits should therefore mainly reflect variation in inframarginal profits (or possibly quasi-rents).

Recently, both in 2018 and 2020, the Norwegian government auctioned new aquaculture production capacity. Unlike previously, when firms were allocated full licences, the recent auctions have mainly allocated marginal capacity. The consequence is that existing aquaculture firms have bought additional marginal capacity that they can put into production using existing infrastructure. Hence, the auction prices will reflect the market value of marginal capacity. More importantly, the variation in auction prices will reflect variation in marginal profits for individual firms, and therefore variation in inframarginal profits. A firm that can put new capacity into place and therefore improve efficiency and profits, will likely have a higher willingness to pay than other companies with lower efficiency/productivity gains.

The remainder of this paper is as follows. The next section summarises the relevant literature on accounting and economic profits, and economic rents in the fisheries literature. Section 3 describes the methodology we use, and section 4 describes the data. Section 5 presents and discusses the result, and the last section concludes.

2.3. Accounting profits, economic profit and economic rents

There is considerable confusion surrounding the definition and source of economic rents and inframarginal profits in the fisheries literature (Arnarson, 2008; 2011). Terms that often are used interchangeably. It is therefore important to clarify the various concepts of profits and rents, before attempting to quantify them.

This section relies heavily on Arnarson (2011) and Arnarson and Bjørndal (2020). The concept of rent can be illustrated using the following diagram (Figure 3, see Alchian (1987)) for some economic good. The figure shows the demand and supply curves, the latter being independent of the price and therefore vertical (fixed supply due to a limiting factor, e.g. by nature). Note that the demand curve in Figure 3 represents marginal profits of using the factor. The fixed supply curve suggests that the fixed quantity, q, would be produced even when the market-clearing price, p, is zero. Consequently, the entire price would represent the surplus per unit of quantity, and the rectangle $p \cdot q$ the economic rent that can be attributed to the limiting factor that fixes supply.

In addition to economic rent, the total economic profits of the supply q also include the demanders' surplus, the triangle in Figure 3 above the economic rent rectangle. The demanders' surplus is often also referred to as inframarginal rents (Arnarson, 2011). In Figure 3, total profits would be higher than economic rents.

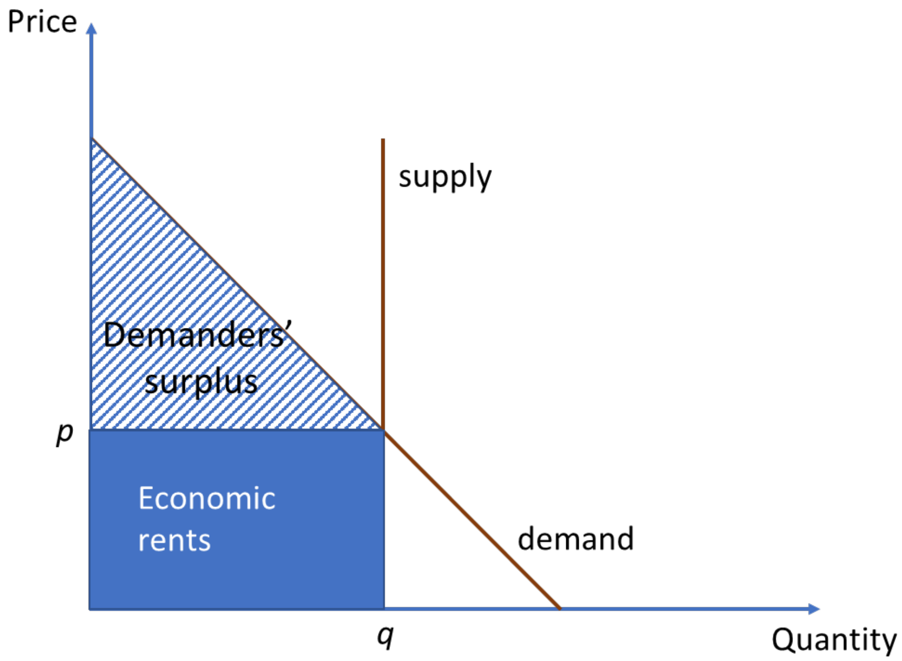

Figure 3. Economic rent.

The diagram above does not fully capture the inherent characteristics of fisheries and aquaculture. The Fisheries literature describes the limitations of economic profit as described in Figure 3 (see e.g. Arnarson, 2011; Arnarson et al., 2018, Arnarson and Bjørndal, 2020). In both industries, supply is not fixed by nature, but by regulations. In fisheries, most commercial fish stocks are subject quotas and other forms of regulations. Indeed, it is possible to capture more or less than the regulated amount from the fish stock. If fisheries are not regulated, i.e. free access, supply will be higher than the regulated quantity, and economic rents will disappear. At the other extreme, the supply is determined by one owner/manager of the fish stock maximising the value of the fisheries by restricting the fisheries, and therefore the supply will be lower than the regulated amount. Variations in fisheries management levels that can be found in between the two extremes result in different levels of restrictions.

Similarly, in salmon aquaculture supply is restricted, not by nature, but by a set of regulations, such as licenses, localities and impact on wild salmonids. As in fisheries, there are two extremes compared to the regulated quantities. One extreme where quantities are not regulated, i.e. free access. In this case, economic rents would disappear. At the other extreme, quantities are restricted by an owner or manager in order to maximise profits.

Arguably, supply in fisheries and salmon aquaculture, is not absolutely fixed, and a definition of economic rent that is based on this is insufficient. As Arnarson and Bjørndal (2020) point out, "*what is crucial for the existence of rents is not fixed supply but that slightly weaker requirement that the marginal cost of supply be less than the demand price*". Hence, motivating a more general definition of economic rents (see e.g. Robinson, 1938; Worcester, 1946; Alchian, 2008): "*Economic rents are payments (imputed or otherwise) to a variable above the marginal costs of supplying that variable*". The resulting diagram describing this definition of rents is found in Figure 2 (see Arnarson and Bjørndal, 2020).

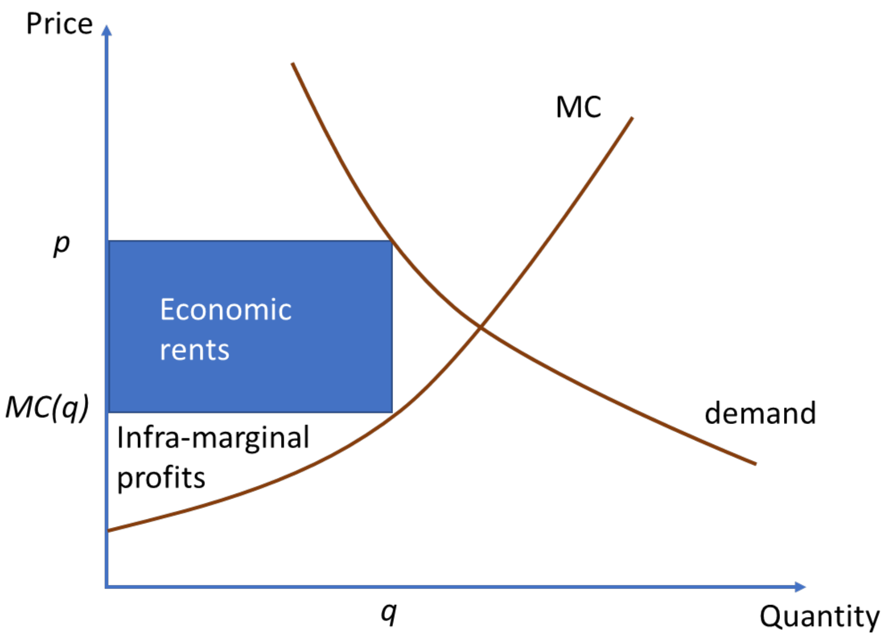

Figure 4. Economic rent.

Note that the marginal cost of supply is represented by the curve MC. Also, in Figure 3 the demand curve depicted the marginal profits, while in Figure 4, the difference between the price *p* and the MC-curve represent the marginal profits at quantity *q*.

If supply is unrestricted, the intersection of the two curves, where MC=D, is the profit maximising equilibrium. In this case, there is no economic rent. On the other hand, if quantity is restricted to *q*, e.g. due to regulations, the demand price rises to *p*. In this case, there is economic rent, given by the rectangle $q \cdot (p - MC(q))$. Infra-marginal profits can be found in the area between the economic rent rectangle and the MC curve.

As shown above, rents are not the same as profits. According to Arnarson and Bjørndal (2020), in the most plausible case with a strictly concave profit function and positive fixed costs, the relationship between profits and rents is indeterminate. If fixed costs are zero, total profits are equal to the sum of infra-marginal profits and economic rent, as seen in Figures 3 and 4 above.

Hereto, profits and rents have been described using a simple example with one limiting factor. In practice, a firm's profit will be affected by many variables, such as produced quantity, technology, capital, entrepreneurship, natural resources stocks, expectations, prices, marketing effort, etc. A generalised profit function $\Pi(q, z)$, where q is the quantity of the variable and the vector z all other variables that affect the profits can be written as

$$R(q, z) = \Pi_q(q, z) \cdot q \qquad (1)$$

where $\Pi_q(q, z)$ are the marginal profits of the variable *q*, and *R* denotes rents. Eq. 1 shows that economic rents is a function of all the variables in the profit function, and not just attributed to a single factor. In principle, all the variables in the profit function can generate rents. Attributing rents to all the various variables in the profit function thus becomes a daunting task. Arnarson and Bjørndal (2020) argues that claiming that a subset of the variables is solely responsible for the profits is misleading. For instance, setting the level of one of the necessary variables such as labour to zero would lead to zero profits, even though some of the other variables are restricted (but not zero).

Rents from each of the independent variables, *i*, in the profit function can be described as

$$R(\boldsymbol{q}; i) = \Pi_{q(i)}(\boldsymbol{q}) \cdot q(i) \qquad (2)$$

and total rents, *TR*, from all the variables in the profit function are calculated as

$$TR(\boldsymbol{q}) = \sum_{i=1}^{I} R(\boldsymbol{q}; i) \quad (3)$$

Some of the variables in the profit function are heterogenous because they are not equally productive. One example is locations or sites for salmon farming. Some sites are known to be more productive due to favourable environmental conditions (e.g. salinity, tides, currents, seawater temperature, oxygen levels, carrying capacity of the seabed and surrounding seawater). Sites with more favourable environmental conditions cam give rise to a differential rent compared to lower quality sites.

Separation rents from intramarginal profits is therefore very challenging empirically. There are several ways of identifying economic rents. Typical approaches in the fisheries literature includes using production functions (Arnarson et al., 2018) or accounting data (e.g. Flaaten, Heen and Matthiasson, 2017; Greaker, Grimsrud and Lindholdt, 2017; Byrne, Agnarsson and Davisdottir, 2019; Gunnlaugsson et al., 2020). While this is possible also for the salmon industry, an approach using market valuation of rent might be more viable. In 2018 and 2020, new production capacity was auctioned to both incumbents and new entrants. These market prices will provide measures of economic rent, but also inframarginal profits. However, the variation in auction prices will provide an opportunity to measure the variation in inframarginal profits. This is the approach of this paper. A benefit of using market prices is that measurement errors related to accounting values are avoided. Accounting information may underestimate economic value due the accounting rules and methods used in preparing financial statements. For instance, book values of assets consist of capitalized historical costs. In some resource industries, historical cost book values will greatly underestimate their economic or market values (Misund, Asche and Osmundsen, 2008, Misund, 2016; 2018; Misund & Asche, 2016; Misund & Nygård, 2018).

2.4. Methods and hypotheses

Estimating resource rent and inframarginal rent is difficult empirically. Economic rent is a latent variable, and therefore requires applying models to try to isolate rents from other elements such as inframarginal profits. Moreover, there are different types of rents, such as regulatory rent, scarcity rents, and other types of rents arising from other variables in the production function. Arnarson and Bjørndal (2020) identify three types; production, permit and site rents, but argue that it is very difficult to disentangle these from each other. This paper will not attempt to quantify economic rents directly but will infer them from auction prices for new production capacity. Moreover, we will estimate the variation in auction prices, and use this to ascertain the inframarginal profits.

This approach differs from other studies for estimating rents in the fisheries literature. These typically follow three approaches. The first, followed by e.g. Arnarson (2011), Arnarson et al. (2018), involves estimating inframarginal rents from profit functions. The second strand uses survey data to estimate the marginal cost and revenue curves, which can then be used to attribute total profit to economic rent and inframarginal profits (e.g. Coglan and Pascoe, 1999). The third, and most numerous, derive resource rent from reported profits adjusting for opportunity costs and government transfers (e.g. Lindner et al. 1992; Flaaten and Wallis, 2001; Nielsen et al., 2012; Grimsrud et al., 2015; Squires and Vestgaard, 2016; Jensen et al., 2019; Flaaten et al 2017 ; Gunnlaugson et al., 2020). A severe limitation of the third approach, compared to the first two, is that inframarginal profits are (implicitly) assumed to be zero.

Since inframarginal profits are determined by firm characteristics (differences in efficiency and diminishing productivity), we can build an empirical model where the willingness to pay (measured by auction prices) is explained by measures of firm characteristics such as efficiency, profitability, size etc.

A generalized model

$$AP_i = a + \boldsymbol{b}\boldsymbol{X_i} + e_i \tag{1}$$

Where the AP_i are the auction prices for capacity bought buy firm *i*, $\boldsymbol{X_i}$ is a vector of measures of firm characteristics with associated coefficients $\boldsymbol{b}$, and a intercept and e_i the error term.

The next step is to identify relevant measures of firm characteristics, where variation in these firm characteristics measure variation in inframarginal profits. We can draw on the accounting literature to find relevant economic measures of firm characteristics.

Relevant measures can be found in the following groups

1. Profitability
2. Solvency and leverage
3. Liquidity
4. Operational efficiency
5. Size
6. Industry specific

Profitability measures seek to quantify the ability of a firm to generate profits. Typical measures are profit margins (such as operating margin and net profit margin) or return on capital (such as return on equity, return on assets, or return on capital employed). Solvency and leverage ratios provide information on how investments in assets are financed. Examples of a solvency measure is the equity ratio, a ratio of equity to total assets, while leverage can be measured by e.g. the debt to equity ratio. Liquidy ratios, such as the current and quick ratios, can indicate a firm's ability to repay short-term debt using their current assets such as inventory, receivable or cash. Operational efficiency ratios measure a firm's ability to use, or turnover, its assets to generate sales or income. An improvement in efficiency ratios will usually translate to increases in profitability. Other relevant measures are size and industry specific ratios, such as feed conversion rates and capacity utilization.

Table 1 below shows the ratios used in this paper to measure firm characteristics.

Table 1. Firm characteristics measures

Category	Measure	Calculation method
Profitability	Return on assets (ROA)	Operating profit (earnings before interest and taxes) dividend by total assets
Solvency and leverage	Equity ratio (ER)	Total shareholders' equity divided by total assets
Liquidity	Quick ratio (QR)	Current assets less inventory, divided by total short-term liabilities
Operational efficiency	Asset turnover ratio (AT)	Total sales divided by total assets
Size	Number of aquaculture licenses (LIC)	Number of aquaculture licenses
Industry specific	Feed conversion rate (FCR)	Total feed used divided by total production
	Production to capacity (P2C)	Total production of farmed salmon and trout divided by MAB (capacity constraint)

Equation 1, operationalized using the variables in Table 1, becomes

$$AP_i = \alpha + \beta_1 ROA_i + \beta_2 ER_i + \beta_3 QR_i + \beta_4 AT_i + \beta_5 LIC_i + \beta_6 P2C_i + e_i \qquad (2)$$

Since we collect data from both 2018 and 2020, we include a year dummy, D_{2020}, which is 1 for observations in year 2020, and zero for observations in 2018, in order to capture price effects from the two auctions. The final model becomes

$$AP_i = \alpha_0 + \alpha_1 D_{2020} + \beta_1 ROA_i + \beta_2 ER_i + \beta_3 QR_i + \beta_4 AT_i + \beta_5 LIC_i + \beta_6 P2C_i + e_i \quad (3)$$

Hypotheses

The null hypothesis is that inframarginal profit cannot explain the variation in auction prices. Significant coefficients on the explanatory variables provide evidence in favour of the alternative hypothesis.

2.5. Data

In 2017, Norway implemented a new regulatory regime for salmon farming. According to this system, all aquaculture sites are organised in 13 production areas (PA). Each year, a group of scientists analyse the impact of salmon lice on wild salmon in each of the PAs, and award them with either a green, yellow or red “traffic light” dependent on the sea lice status of wild salmonids. Based on the annual sea lice reports from scientists, the Norwegian Ministry of Trade and Industry, determine which PAs are allowed to grow and which PAs need to cut back on their production through restrictions in biomass limits (MAB). PAs with a high likelihood of a negative impact of sea lice on wild salmonid health and survival are given a red color, while a green color is attached to the PAs with an low level of sea lice, and yellow for PAs with acceptable levels of sea lice. The system is based on bi-annual adjustments. According to the system, MAB levels in green PAs are allowed to grow by 6% bi-annually, while red PA MAB is reduced by 6%. There is no change in MAB for yellow PAs.

New capacity (6%) in green PAs are allocated by two separate systems. First, a portion of the 6% (2% in 2018 of 1% in 2020) are sold on at a fixed price per tonne MAB for owners of existing aquaculture licenses. Farmers in green PAs can achieve this by way of application to the Directorate of Fisheries.

The second portion of the 6% growth (4% in 2018 and 5% in 2020) in green PAs is allocated through an auction system, which is available to both existing and potential new owners of aquaculture licenses. Aquaculture firms submit bids primarily through and open digital auctioning process, and where capacity is awarded to the highest bidder. The number of rounds per auction were predetermined. There were also written (closed) auctioning processes, but mainly for smaller, remaining quantities unsold in the first auctions. The details of the auctioning process in 2018 is described in Okholm and Gallagher (2018).

We collect data from the auctions of marginal production capacity in June and September 2018, and August 2020 (Table 2).

Table 2. Auction data from June and September 2018, and August 2020.

	June 2018	September 2018	August 2020
Number of observations	41	6	30
Sold capacity (tons MTB)	14,945	414	27,189
Total value (NOK million)	2,915	81	5,975
Average value (NOK thousand / tonne MAB)	195,071	194,145	219,759
Variation in average value (standard deviation of average value, NOK)	34,356	52,227	25,535

Table 3 contains the accounting and industry specific data used to calculate the performance measures in Table 1. The data is provided by the Directorate of Fisheries and are based on surveys carried out annually. The total number of auction prices is 77, but due to missing data for some of the firms, the number of observations (N) is 42.

Table 3. Descriptive data – Accounting and operational data (N=42).

Measure	Average	Standard deviation	Max	Min
Auction prices (AP), NOK/tonne MAB	203,602	35,446	257,079	132,000
Return on assets (ROA)	0.22	0.22	0.79	0.18
Equity ratio (ER)	0.46	0.16	0.78	0.25
Quick ratio (QR)	1.31	0.84	3.39	0.32
Asset turnover ratio (AT)	0.83	0.16	1.47	0.63
Number of aquaculture licenses (LIC)	22.2	26.1	67.0	1.0
Feed conversion rate (FCR)	1.28	0.23	2.04	0.98
Production to capacity (P2C)	1.66	0.40	2.99	0.72

Table 4 suggests high correlations among some of the variables. This can potentially create issues for the significance of the variables, and we therefore carry out a VIF-test post-regression.

Table 4. Correlation matrix

	ROA	ER	QR	AT	LIC	FCR	P2C
ROA	1.00						
ER	0.23	1.00					
QR	0.38	0.79	1.00				
AT	0.21	–0.01	–0.02	1.00			
LIC	–0.40	–0.72	–0.68	–0.12	1.00		
FCR	0.24	0.20	0.34	0.31	–0.22	1.00	
P2C	–0.30	0.01	–0.17	–0.09	0.21	–0.59	1.00

2.6. Results and discussion

Table 5 presents the results from the regression of auction prices on measures of firm performance in different dimensions. Since some of the explanatory variables had high levels of correlation, a VIF-test was carried out (Table 6), but the VIF-values are lower than 5–10, which are considered rules of thumbs limits for VIF-values.

The model explains approx. 55 percent of the variation in auction prices, suggesting that variations in firm characteristics have an important impact on a firm's willingness to pay for new production capacity.

The signs on the coefficients seem to suggest that auction prices were highest for smaller firms (negative coefficient on licenses), firms that are the most solvent (positive coefficient on equity ratio) and profitable (positive coefficient on return on assets), and firms that are the least efficient (positive coefficient on feed conversion rate and negative coefficient on asset turnover).

Four of the coefficients are statistically significant, two intercepts and the parameters on the equity ratio ($p<0.05$) and asset turnover ($p<0.10$). Asset turnover is a measure of efficiency and provides information on how efficiently the firms are able to generate profits or sales from their assets. The results suggest that firms with lower levels of efficiency are willing to pay the most for new capacity. The interpretation is clear, the firms that have the most to gain from increasing their efficiency, are the most willing to pay higher auction prices. This is a strong indication of the importance of inframarginal profits in partly determining auction prices.

A high equity ratio tells us that a firm is very solvent, and less susceptible for adverse market conditions. This variable is strongly linked to credit risk, the likelihood that firms default on their debt obligations (Misund, 2017). The results suggest that firms with higher equity ratios have a higher willingness to pay for auction prices. This could partly be explained by profitability, but also by lack access to equity capital[1]. The firms that paid the most for capacity tended also to be the smallest firms. Previous research suggest that smaller firms are more profitable than larger firms (Asche & Sikveland, 2015; Asche, Sikveland & Zhang, 2018).

[1] Risk and return of stock exchange listed salmon farming companies are described in recent studies (see e.g. Misund, 2016; 2018; Misund and Nygård, 2018).

Another explanation could be access to equity capital. The high equity ratios suggest that these companies have balance sheets that are solid and have more debt capacity. A handful of the larger salmon farming companies are listed on a stock exchange and can easily issue more shares in order to collect capital for new investments (Misund, 2018; Misund and Nygård, 2018). The smaller companies, however, will not have the same access to equity capital, and may rely on debt. Not debt in the form of bonds, but bank loans. In order to finance investments in new capacity, smaller firms will be more reliant on debt financing, which can explain that firms with higher equity ratios have a higher willingness to pay for new capacity.

Table 5. Regression results

	Coefficient	t-stat	p-value	Model
Intersect	-2.91×10^{7}	–2.20	0.035	
P2020	14,510.3	2.21	0.034	
LIC	–32.2	–0.15	0.884	
FCR	7,556.3	0.42	0.680	
ER	134,778	2.35	0.025	
QR	–8,641.5	–0.75	0.461	
ROA	10,099.0	0.39	0.696	
AT	–45,596.1	–1.94	0.061	
P2C	78.8	0.01	0.995	
R2				0.555

N	42
F(8,33)	9.77***

The positive coefficient on the 2020 dummy is in line with a higher average price of capacity during the 2020 round compared to the 2018 auction round.

Table 6. VIF-test

Variable	VIF	1/VIF
ER	3.85	0.26
QR	3.52	0.28
LIC	2.69	0.37
FCR	2.06	0.48
P2C	1.91	0.52
D_{2020}	1.76	0.57
AT	1.56	0.64
ROA	1.50	0.67

2.7. Conclusion

Estimation of economic rent is challenging for many reasons, particularly due to its elusive nature and widespread confusion amongst academics as to how to identify and quantify different sources of economic rent. Accurate rent estimations require that inframarginal profits are not ignored but estimated alongside rent. Ignoring inframarginal profits will overestimate economic rents, which could be problematic since in some industries inframarginal profits can be substantial.

Our results suggest that salmon aquaculture is one of these industries with substantial inframarginal profits.

Auction of salmon production capacity from 2018 and 2020 provide estimates of the market values of salmon farming licenses. These market values will consist of both economic rent and inframarginal profits. Since economic rent in the form of regulatory rent will be same for all companies, the variation in auction prices/market values should be caused by variation in inframarginal profits.

We find that companies that are less efficient have a larger willingness to pay for marginal production capacity than larger salmon farming companies do, suggesting that inframarginal profits are important in explaining the variation in willingness to pay for new production capacity.

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3. Paper 2 «Sustainable growth, resource rent and taxes in aquaculture»

3.1. Abstract

Global aquaculture represents an opportunity for sustainable growth in supply of healthy food and private and public income, but also has environmental footprints and thus requires a balanced policy approach by governments. Salmon aquaculture has until recently experienced rapid growth, and periods of high profitability. In all producer countries, salmon aquaculture is subject to different regulations that indirectly restrict output at the firm level and may restrict global supply in the short run. The sector has become a candidate for extraordinary taxation in Norway, and a tax regime which is unique in the context of global food production is under consideration. An argument is that society allocates sea locations to salmon firms for free, and that these provide economic returns well above normal returns to capital due to the number of sites being limited, both in Norway and globally. This paper uses a panel data set to analyze patterns of productive performance and profitability in Norwegian salmon aquaculture to analyze whether these patters suggest economic rents or inframarginal profits. We find significant variations in productive and economic performance over time and across firms, a variability that is inconsistent with a claim that all the economic profits are a resource rent generated by a natural resource in the form of limited aquaculture sites. Our results suggest that inframarginal profits are important part of total profits in the salmon aquaculture sector.

3.2. Introduction

Salmon aquaculture has until recently experienced rapid growth, and periods of high profitability. In all producer countries salmon aquaculture is subject to different regulations which indirectly restrict output at the firm level and may restrict global supply in the short run (Anderson et al., 2019). Growth has been made possible by innovations, population growth and income growth. Process and product innovations have contributed to productivity growth (Tveterås, 1999; Asche, Roll and Tveterås, 2008; Asche, Guttormsen and Nielsen; 2013; Asche et al., 2013) and increasing global demand for salmon products among consumers (Brækkan and Thyholdt, 2014; Brækkan et al., 2018). Over the last decades, the salmon sector has been subject to increased scrutiny due to biological and environmental problems related to fish diseases, effects on stocks of wild salmonid fish, and other emissions from farms (Asche, Guttormsen and Tveterås, 1999; Asche et al., 2009; Torrissen et al., 2013; Abolofia, Wilen and Asche, 2017; Asche, Cojocaru and Sikveland, 2018). Salmon aquaculture has experienced business cycles reflected in fluctuations in production growth rates, prices and profits (Asche et al., 2018).

Salmon farming is basically a process of knowledge- and capital-intensive animal husbandry, with several biological risks at different stages of the production process. In Norway, the government's aim is to increase the production significantly in a sustainable manner, and it has introduced several regulations aimed at facilitating sustainable growth.

Salmon aquaculture has been allocated coastal farm locations and license to produce through different mechanisms by national governments. Recently, the sector has received increased attention as a candidate for extraordinary taxation in Norway (NOU 2019:18). An argument is that salmon farms has been granted a license to produce at locations owned by the public, and that farm sites provides extraordinary productivity and profitability due to free services from the nature in form of inflows of sea water with appropriate conditions, and ability to process emissions from aquaculture.

One can argue that further sustainable growth in Norwegian salmon production is possible the next decades with a properly designed policy regime that provides sufficient incentives to investments in innovation and plants at different stages of the value chain. By 'sustainable' we mean, consistent with UN's sustainable development goals, a growth that balances economic, social and environmental concerns of society. One aspect of the economic dimension is that capital and labor inputs are paid competitive wages relative to alternative employment in other sectors. Another aspect is that taxes and subsidies (e.g. R&D subsidies) are appropriately balanced with respect to government revenue needs, correction of market distortions and failures, and provide sufficient incentives for investments.

In this paper we analyze some key features of salmon farming to shed some light on implications for taxation. Section two presents important features of salmon aquaculture production processes, discuss government policy objectives and regulations, and discusses taxation issues. Section three provides an empirical analysis employing a panel data set on Norwegian salmon firms on patterns of productive and economic performance. Section four discusses future growth and some implications for taxation. Section five provides a summary and conclusions.

3.3. Salmon aquaculture: Production process, policies and performance

This section first provides a description of the production process in salmon aquaculture, focusing on the biological process and 'services' from nature. Then we discuss policies and regulations aimed at salmon aquaculture, with a focus on the leading producer country Norway. We continue with a section presenting the current taxation of aquaculture and a discussion of arguments related to taxation of salmon aquaculture. Finally, we discussed the interlinked issues of future international competitiveness, innovation and sustainable growth.

3.3.1. Salmon aquaculture production processes

Until now salmon have been farmed in open cages in seawater. The capital equipment of salmon farms includes cages, a floating barge for production surveillance room and feed storage, anchoring systems, and feeding systems. The production technology is highly automated through feeding systems and digital sensor technologies for monitoring the environment and live salmon. The role of the farm manager and labor is primarily monitoring of the farm, making feeding decisions, maintenance and assisting release and harvesting of live salmon in and out of the cages.

A typical salmon farm is of a scale that in production volume and sales revenue is many times larger than a typical agricultural livestock farm in most OECD countries. It may harvest in the range of 2000–6000 metric tonnes of salmon each year, and if the farm gate sales price is 40 NOK per kg this represents a sales value of 80–240 million NOK.[2] The most important inputs in terms of production

[2] With an exchange rate of 10 NOK/EUR this is equivalent to a sales value of 8-24 million EUR.

cost shares are feed (42–50%), salmon fingerlings, called smolts (9–11%), capital equipment depreciation (5–6%), and labor (7–8%).

The biological production process in salmon farming is basically one where salmon feed is converted to salmon biomass through growth. Farmed salmon are reared in open cages and rely on inflows of clean water with appropriate salinity, oxygen content and temperature. The flow of water also transports nutrients and faeces away from the cages, contributing to a healthy living environment for the salmon. Like other farm animals, salmon will not realize its potential in terms of feed digestion, growth and survival rates without an environment that provides sufficiently high levels of animal welfare.

Until now salmon has been farmed in the coastal zone which is sheltered from the open ocean waves and winds. Through innovations which have led to more robust cages and other capital equipment salmon farms have gradually moved to farm sites more exposed to waves and winds, but also with greater water exchange and carrying capacity. The natural characteristics of water flows, sea temperatures and topographical conditions below the water surface influence the carrying capacity of a farm location, in terms of the total salmon biomass and production at the farms site, and the densities of salmon in the cages.

There are economies of scale in farm site production up to some levels related to capacity utilization of fixed inputs such as feed barges, cages and other capital equipment. Hence, a location with high bioproductivity and carrying capacity allowing for high salmon output and productivity levels can achieve lower unit production costs and higher profits. Potential farm sites along coastlines with appropriate conditions for salmon farming have different biophysical characteristics. If farm sites are sufficiently scarce and heterogeneous one can hypothesize that there are Ricardian or differential rents to be earned from the more productive locations. Later, we will discuss the issues of location scarcity and differential rents.

Traditional Ricardian models of resource rent imply deterministic production processes, with no biological shocks which affect the absolute and relative productivity of different farm locations.

However, this is not an appropriate representation of salmon aquaculture production processes. Like other live animals, salmon can be affected by diseases and parasites, such as sea lice. Biological and economic losses from diseases and parasites due to lower growth rates and higher mortality rates can be caused by production technology and practices, but also by the exposure of the location to external disease pressure from other farm sites and other human activities and natural conditions in the sea that entail disease risk. The history of salmon aquaculture has shown that there is a significant underlying biological risk caused by diseases and parasites. The magnitude of production risk has been estimated in several econometric studies (Tveteras, 1999; 2000; Kumbhakar and Tveteras, 2003), and compared with agriculture (Flaten, Lien and Tveteras, 2011).

It is obvious that there are risks of negative external effects within the salmon aquaculture sector in a geographic region. These external effects are related to hydrodynamic conditions in the region influencing the transport of infectious diseases and sea lice, the geographic configuration of farm sites in terms of proximity and location with respect sea currents, and production practices at farm sites. It can be argued, given technology and production practices, that the risk of disease losses in a region increases with farms' geographic proximity, and total biomass of live salmon at farms in the region.

It follows from the above that the potential productivity of an individual farm location is also influenced by its exposure to external disease and sea lice risks. From an economic point of view the bioproductivity of a farm location can be characterized both by its expected (mean) level of primal and economic productivity, and by the riskiness of its primal and economic productivity. In section three we will provide an empirical analysis of the nature of risk of salmon aquaculture at the firm level.

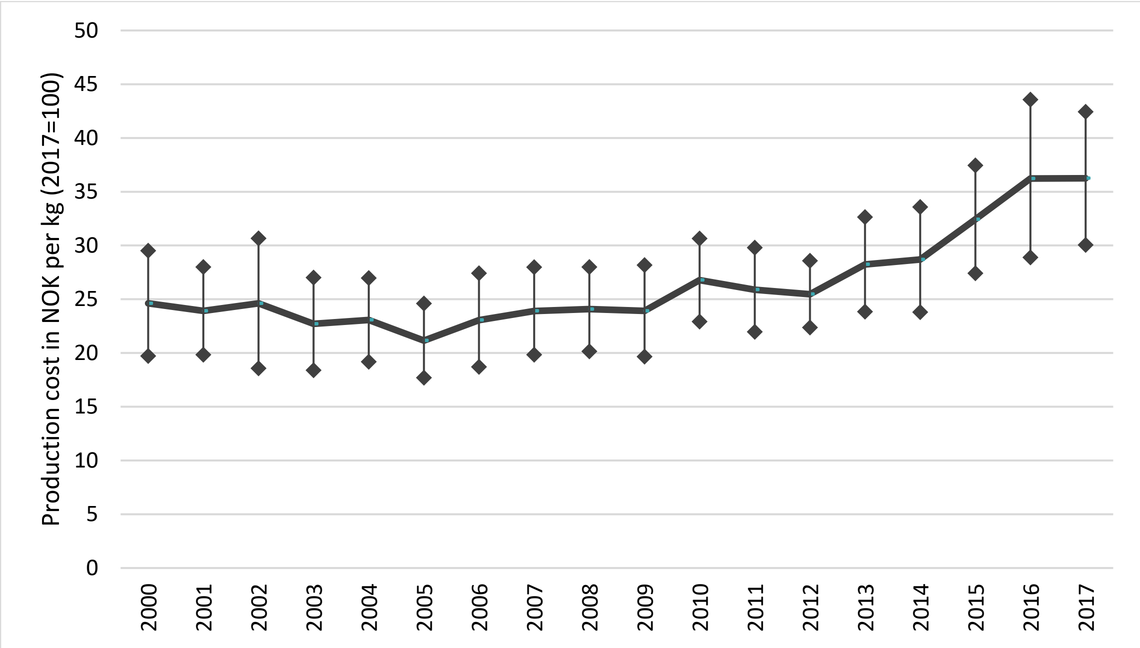

Figure 1. Average and st.deviation of inflation adjusted production cost per kg of salmon of Norwegian salmon firms. The vertical lines represent +/– one st.dev. Data source: Norwegian Directorate of Fisheries

Another source of externalities in salmon aquaculture is potential negative effects on wild stocks of salmonid fish through escape of farmed salmon (Pincinato et al., 2020), and sea lice from farmed salmon to wild salmonids (Torrissen et al., 2013; Abolofia et al., 2017). For owners of salmon fishing rights in rivers and recreational fishers this can lead to economic losses and reduced welfare. Organic emissions from salmon farms may also represent a negative externality to the marine environment if it is not sufficiently able to assimilate organic material and nutrients.

We present two figures depicting the development of production costs in Norwegian salmon farming over time. Figure 1 plots the average and standard deviation of inflation adjusted production cost per kg of salmon of Norwegian salmon firms participating in the survey of the Norwegian Directorate of Fisheries. This survey typically collects data from the majority of salmon firms each year. We see that after a decline of production costs from 2000 to 2005, costs have increased afterwards. The variability of production costs as measured by the standard deviation have also increased, particularly in the last two years.

Figure 2 shows the development in inflation adjusted production costs per kg from 2005 to 2017. It is based on firm level data, where firms have been sorted by their production costs. This is based on a sample of salmon firms representing the majority of total production. We have scaled up the production volume of firms in this sample so that the total volume is equal to total Norwegian salmon production in the respective years. Each year we see big differences in average production costs between low-cost producers and high-cost producers. A question is to what extent these cost differentials are caused by resource rents related to different biological conditions, or quasi rents related to technology, quality of management, government regulation etc. Another question is to what extent the relative cost performance of individual firms is stable due to more or less permanent rent differentials, or fluctuates due to shocks, e.g. biological shocks caused by diseases. In section three we will investigate this further.

Assuming that the sample is fairly representative each year we see that real production costs have shifted upwards from 2005 to 2017. Since the state of technology and skills have not declined, it is most reasonable to relate these upwards shifts to input prices increasing faster than inflation over time or increasing negative biological shocks (external effects) over time. Recent evidence suggests that costs related to treatment and prevention of sea lice infestations have become an important component of production costs (Abolofia et al., 2017; Iversen et al., 2020).

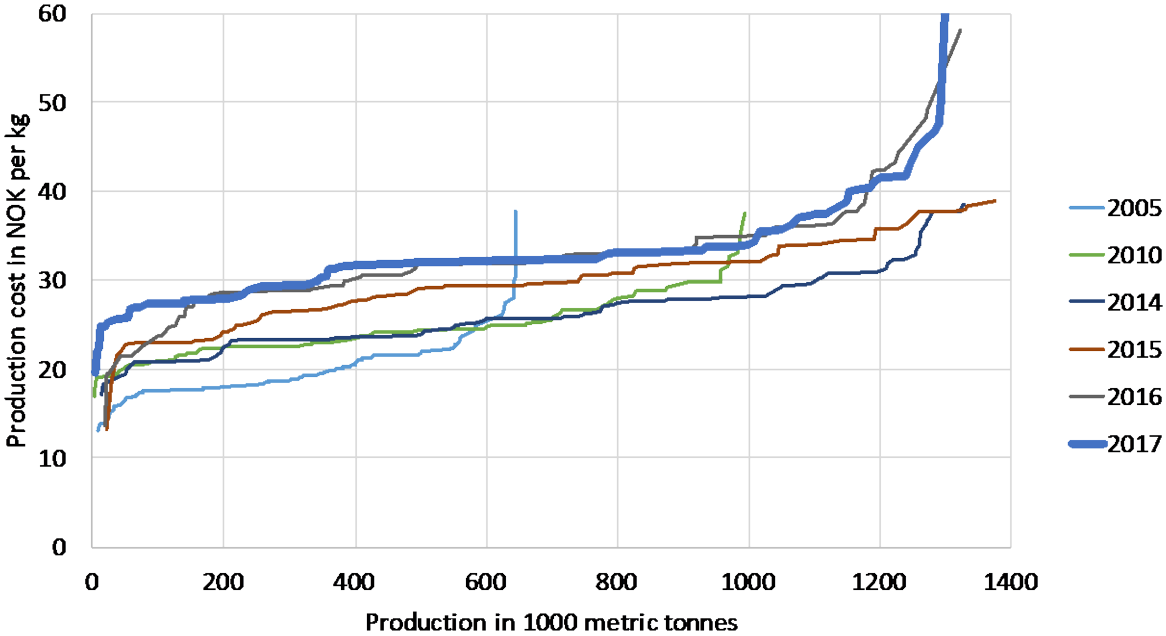

Figure 2. Development of production cost per kg 2005–2017. Inflation adjusted (2017=100). (Data source: Norwegian Directorate of Fisheries)

3.3.2. Policies and public regulation

Aquaculture is a sector which represents both opportunities and challenges for society and government across countries. On the one hand, aquaculture can provide healthy nutrition, employment and income opportunities. On the other hand, as indicated above, it has biological and environmental externality risks which implies that it is a candidate for public regulation to mitigate market failures. Due to its mix of challenges and opportunities aquaculture is a sector which is interesting to assess in terms of UN's 2030 agenda for sustainable development and UN's sustainable development goals.[3] These goals cover a very broad set of challenges facing the globe, including poverty (goal 1), hunger (goal 2), decent work and economic growth (goal 8), responsible production and consumption (12), climate action (goal 13), life below water (goal 14) and life on land (goal 15). The challenge for sustainable growth of aquaculture is to find an appropriate balance between different sustainable development goals. The considerations may be very different across

[3] See United Nations' website www.sustainabledevelopment.un.org. It states that the 17 Sustainable Development Goals (SDGs) '…*recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests.*'

countries and species depending on e.g. economic stage of development, the nature of externalities for the aquaculture species, and the proximity to other user interests.

Salmon aquaculture is an example of a farmed species in which similar production technology is used across countries. Moreover, the salmon aquaculture sector in different countries face similar biological risks and externalities. However, government measures designed to mitigate externalities differ significantly (Gibbs, 2009; Anderson et al., 2019). The policy measures implemented in the main salmon producer countries have also been motivated by other policy objectives, which again have been influenced by the political power of different stakeholders. Policy measures aimed to mitigate externalities, or the absence thereof, have had significant effects on the development of production in salmon producer countries. For the United Kingdom (UK), Canada, and the United States (US), strict regulations have led to lower environmentally sustainable growth than could have been possible. In the more liberally regulated Chilean sector, the absence of proper regulations has led to a disease-driven decline in production since 2008 that could have been avoided (Asche, Hansen, Tveteras, & Tveteras, 2009).

In salmon aquaculture, externalities influence productivity and production (1) directly through diseases and other externalities that cause increased mortality or lower growth rates and (2) indirectly through public regulations and other policy measures motivated by externalities. In theory, externalities provide a rationale for the government to introduce regulations or taxes to mitigate these. In practice, designing appropriate measures may be difficult for governments due to insufficient information about e.g. biological mechanisms and magnitudes of the externalities. Public measures to mitigate externalities can often fail to achieve its objectives because the measures are based on insufficient knowledge and incorrectly designed, or because the measures have unintended effects. Another concern is that measures should stimulate innovations that allows for growth which is more sustainable in terms of the magnitude of externalities, or environmental footprint.

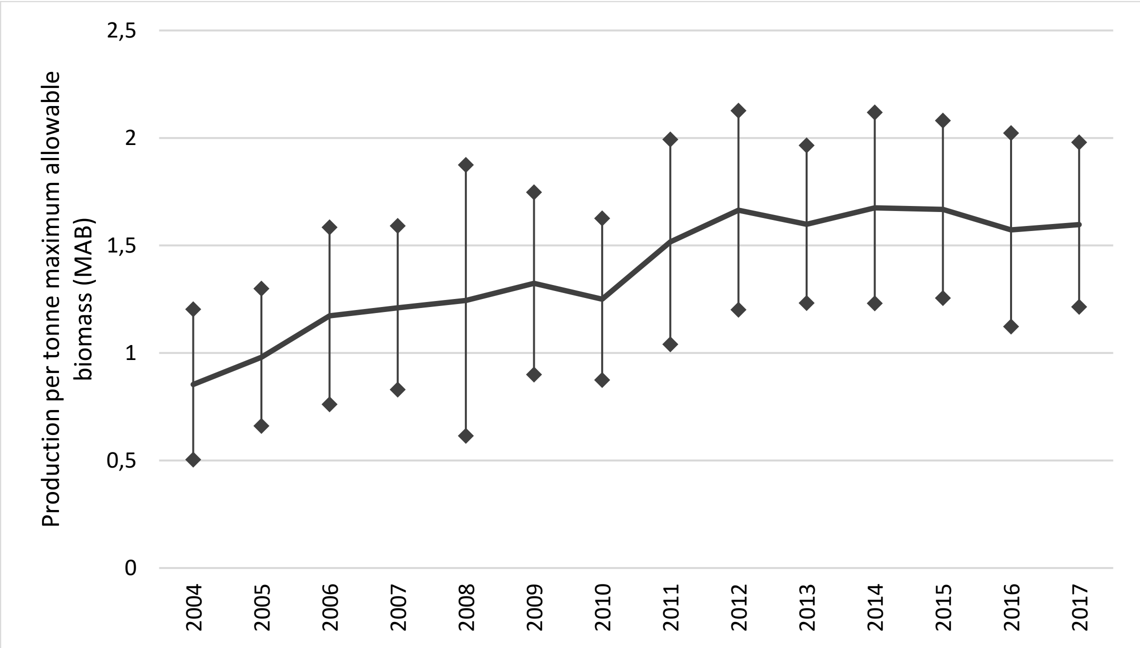

Figure 3. Average and st.deviation of salmon produced per tonne of maximum allowable biomass (MAB) of Norwegian salmon firms. The vertical lines represent +/– one st.dev. Data source: Norwegian Directorate of Fisheries

In Norway, the current policy objective of the government and most of the political establishment is to allow 'sustainable growth' of salmon aquaculture (Meld.St.16 (2014–15)). The sector is regulated in several ways. The stock of live farmed salmon in the sea is restricted by government from the national level to the site level. Individual firms need licenses for maximum allowed biomass (MAB), which limits the maximum biomass of live salmon in the cages at any point in time during the year. Furthermore, firms need a location license to operate a farm at a particular coastal site, which is public property. The government also limit MAB for each licensed farm location, based on an assessment of the biological carrying capacity of the site. Each salmon firm can have several MAB licenses and licensed sites and can move their MAB around to their license's sites. Most firms have several producing farm sites at any given time, and some large firms produce in several regions along the coast.

In practice the government indirectly limit production at the national level through MAB, at the regional level through so-called production areas, and at the farm site level. This is indicated in Figure 3, which shows the ratio of production volume to MAB volume. The MAB regulation was introduced in 2004, replacing a previous indirect production volume regulation through feed quotas. Salmon farmers adapted to the MAB regulation during the first years after its introduction, and eventually reached an average production/MAB ratio of approximately 1.5–1.7. The variation we observe across firms in each year, as represented in Figure 3 by the standard deviation of production/MAB ratio, can be due to the intrinsic quality of firms' aquaculture locations, stochastic biological shocks related to e.g. diseases and sea lice, quality of management, and in particular the firms' ability to exploit the MAB capacity by having a sufficient number of MAB licenses and farm locations which it rotates production between.

A dominant environmental concern in recent years has been sea lice, a parasite which use farmed salmon as hosts, and can be transported from farms to wild salmonid fish, i.e. salmon and trout. The Norwegian government has introduced thirteen regional production areas and a traffic light system with the effects of sea lice on stocks of wild salmonid fish as environmental indicator (Hersoug et al., 2021; Larsen and Vormedal, 2021). If the effects on wild salmonid stocks are assessed as 'acceptable' in a production area then total MAB in that area can be increased, if it is 'moderate' MAB can be kept at current level, and if it is 'unacceptable' then MAB should be reduced according to the regulation.

Government also regulates several aspects of salmon production to safeguard animal welfare and limit escape of farmed salmon, disease outbreaks and various environmental effects to the aquatic environment and other stakeholders. The government's means for maintaining animal welfare and limit externalities through the production process are mandated standards for production equipment and practices, fallowing periods for farm sites (i.e. no production) at regular intervals, mandated reporting of biological and environmental parameters to public agencies, and monitoring and inspections by public agencies.

3.3.3. Taxation of aquaculture

There is a substantial fisheries economics literature on resource rent creation, dissipation and capture in fisheries (Grafton, 1995, 1996; Johnson, 1995; Coglan and Pascoe, 1999; Miller et al., 2000; Asche et al., 2002; Greaker, Grimsrud and Linholdt, 2017; Arnason et al., 2018), and other natural resources such as petroleum (Osmundsen et al., 2015) and hydropower (Amundsen and Tjøtta, 1993; Banfi, Filippini and Mueller, 2005). Although most petroleum countries have implemented some form of resource rent taxation, this is not easily discernible in other natural resource industries such as fisheries. Iceland is one of few countries that has implemented resource rent taxation in fisheries (Gunnlaugson et al., 2018). Norway implemented a fee for aquaculture licenses in 2002, fees which can be considered a type of tax. Furthermore, Iceland, the Faroes and Norway have all recently implemented royalty taxes on salmon aquaculture production.

An important reason for the reluctance by governments to implement resource rent taxation in fisheries and aquaculture is the difficulty in determining the size of economic rent. Profits are poor measures of economic rent in fisheries (Arnarson, 2011; Arnarson et al., 2018) and aquaculture (Arnarson & Bjorndal, 2020). A recent study suggests that inframarginal profits are an important determinant of salmon license market values (Asche, Misund & Tveterås, 2020).

Next, if salmon aquaculture is a potential candidate for extraordinary taxation, one has to analyze the market structure to assess the opportunities for taxation which will not lead to significant deadweight losses compared to taxation alternatives. The salmon market is global and highly integrated in the sense that the price formation for farmed salmon is determined by global supply and demand, with different qualities receiving discounts or premiums relative to the global price. It is argued that appropriate sites for farming are limited or scarce, or that the supply of farmed salmon for other reasons is restricted. The main reason would be government regulations in producer countries limiting production. It is also argued that there is a resource rent – or differential rent – that can be captured through taxes from farm sites with different bioproductivity. It is argued that an appropriately designed extraordinary tax – also called resource rent tax – can provide tax revenue with limited economic efficiency losses for society, i.e. that it is possible to design a relatively neutral tax regime where aquaculture investment projects which are economically efficient for society to initiate will still be initiated by private investors when they have calculated after tax financial returns.

Salmon farming companies in Norway have in recent years experienced high profit rates, as indicated by Figure 4. According to this figure average operating profits have fluctuated significantly over time, but in the best years have been high compared to private sector averages.

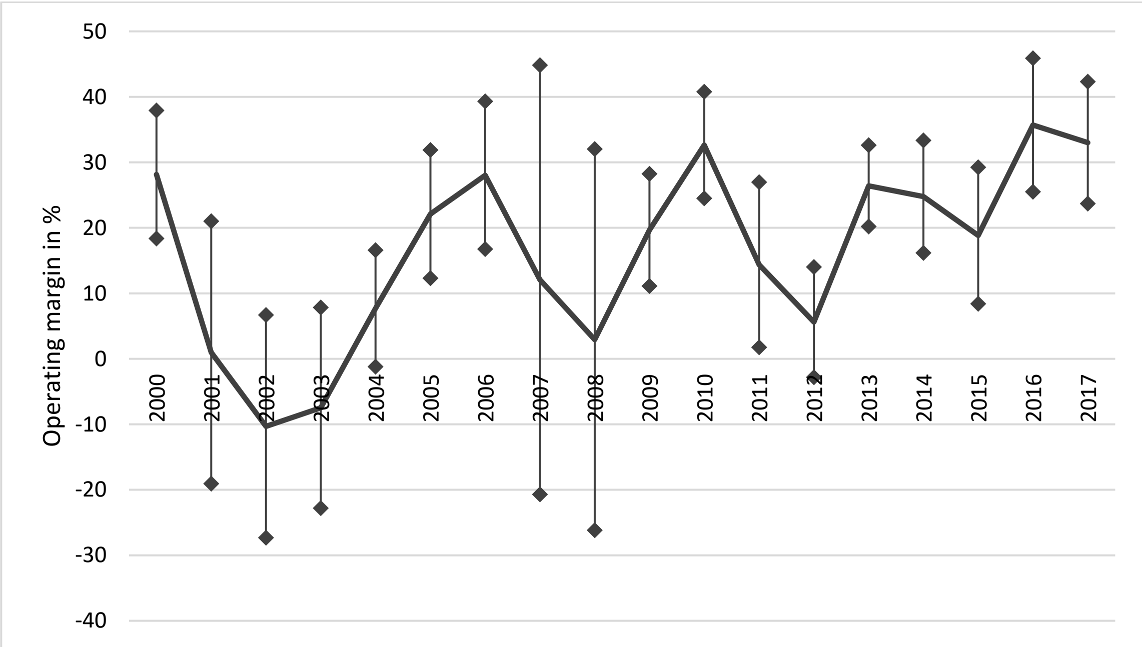

Figure 4. Average and st.deviation of operating margin of Norwegian salmon firms. The vertical lines represent +/– one st.dev. Data source: Norwegian Directorate of Fisheries

In the following we will investigate some of the arguments for an extraordinary tax in salmon aquaculture by providing empirical analyses that can shed some light on these.

3.3.4. International competitiveness, innovation and sustainable growth

Salmon is produced in several countries with appropriate biophysical conditions for salmon aquaculture, broadly speaking sufficiently sheltered coastal zones and appropriate sea temperatures through the year. Salmon aquaculture technology and know-how is available globally through suppliers of capital equipment, feed, pharmaceuticals, and consultancy services, and through multinational salmon companies which operate in several countries. Salmon production volumes and production growth rates have been very different across these countries (Iversen et al., 2020). To some extent this can be explained by biophysical conditions. But as has been argued above, different regulatory regimes may have played a very significant role in explaining countries' different salmon aquaculture growth trajectories. Furthermore, it can be argued that it is possible to produce in a sustainable manner much larger volumes of salmon in some producer countries than we currently observe.

Although salmon may end up as differentiated final consumer products and meals, exported farmed salmon products can be characterized as a commodity as it is difficult to differentiate the attributes of whole salmon or salmon fillets for companies and countries. Salmon farming companies in different countries compete in many export markets, and the price formation is global. What emerges is that the supplied quantity and market shares of salmon from different companies and countries is determined by government regulations limiting production, and firms' productivity and cost efficiency which is largely determined by their biological performance and government regulations.

Here we will discuss some aspects of how a significant extraordinary income or profit tax can affect Norwegian salmon supply in the short and long run. Of course, if government manages to design a neutral tax, i.e. it does not change investment and production decision incentives, then it will not have an effect. But if the tax is non-neutral, then it can have effects through different mechanisms: (1) Location of investments and production outside Norway, (2) investments in aquaculture plants on land, in the coastal zone and offshore, (3) investments in alternative technologies with different environmental effects, (4) vertical and horizontal organization of value chains through e.g. mergers and acquisitions, (5) economic geography of production activities in salmon value chain within Norway.

One can argue that further sustainable growth in Norwegian salmon production is possible the next decades with a properly designed policy regime that provides sufficient incentives to investments in innovation and plants at different stages of the value chain. In the next section we will empirically analyze development in productivity and economic returns over time and across firm and discuss potential implications for policy.

3.4. Empirical analysis of Norwegian salmon sector aquaculture economic performance

This section provides descriptive and econometric analysis of productive and economic/financial performance of salmon aquaculture firms. The purpose is to analyze developments over time, and across firms within a given year. Hence, we want to discuss developments in average productivity and economic performance over time, but also the riskiness of productivity and economic outcomes.

3.4.1. Measures of productivity development

As discussed in section 2, Norwegian salmon firms are restricted by a quota on maximum allowable biomass (MAB) of live fish in the sea at any time. Figure 3 showed the development of production per tonne of MAB over time since 2004, when the MAB regulation was introduced. Firms needed some years to learn how to adapt production to the MAB regulation, but in 2012 reached an average ratio of production in tonnes to MAB in tonnes of around 1.6–1.7. After that salmon firms have largely been able to sustain those ratios on average, but with some decline in the last two data years. Biological shocks in the form of diseases, sea lice etc. can reduce the production/MAB ratio. We see that each year there is substantial variation across firms as indicated by plus/minus standard deviation, again indicating the presence of biological shocks along the Norwegian coast which affect salmon firms unevenly.

The biological production process in salmon aquaculture is basically one of converting salmon feed into salmon biomass growth. Salmon feed typically represents 40–50% of production costs. Hence, a central productivity metric is the feed conversion rate (FCR), i.e. the ratio of salmon biomass growth to feed input volume. Figure 5 shows the development of the average feed conversion rate and its variability as measured by plus/minus one standard deviation. When production is efficient and devoid of diseases and other shocks that influence salmon growth and survival, FCR should be around one. We see here fluctuations in average FCR over time, indicating variations in biophysical shocks influencing biological productivity. Moreover, we see large FCR variation across firms each year as indicated by plus/minus one standard deviation of FCR, indicating the presence of biological shocks along the Norwegian coast which affect salmon firms unevenly.

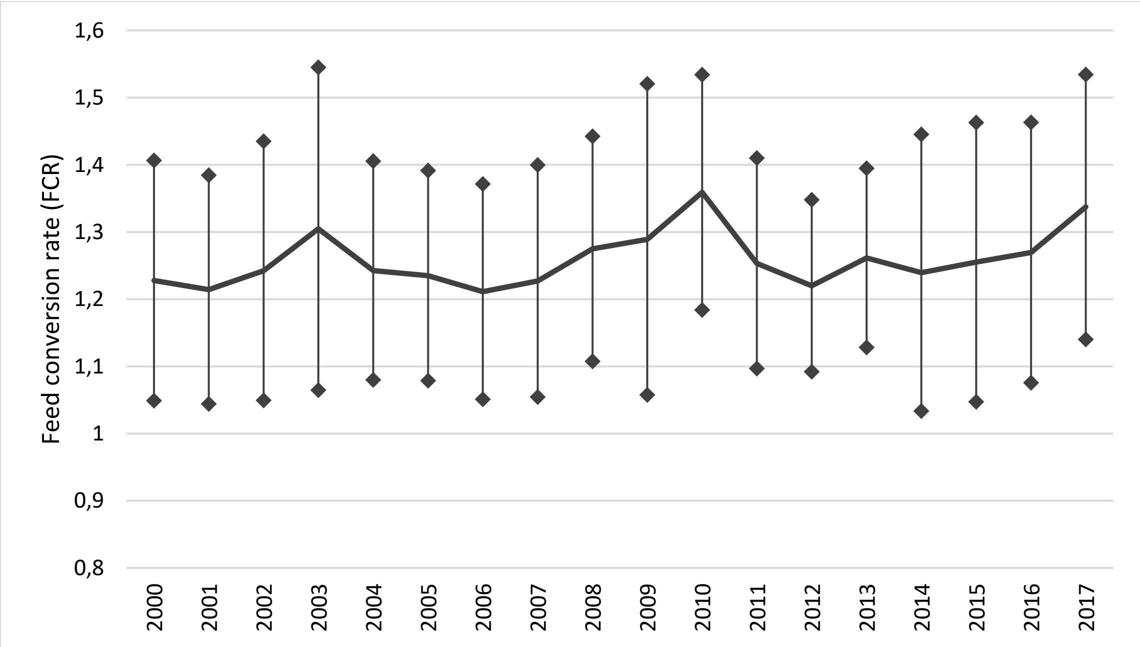

Figure 5. Average and st.dev. of feed conversion rate (FCR) of Norwegian salmon firms. Vertical lines represent +/– one st.dev. Data source: Norwegian Directorate of Fisheries

3.4.2. Economic and financial performance of salmon firms

The economic and financial performance of salmon firms are functions of biological performance, technology and management, and prices of inputs and output. In section two we showed the development of production costs and operating margins over time and across firms. The descriptive analysis showed the recent increase in production costs per kg and also the operating margin. This is consistent with a positive shift in global demand for salmon which dominates shifts in global supply (marginal costs), and also an inelasticity of global supply.

Figure 6 shows the development of average and standard deviation of return of total capital (ROTC) of Norwegian salmon firms. We see the cyclicality of average ROTC over time. In 2002 and 2003 ROTC was negative. In some other years ROTC have also been below 10%, but we also see that in many years ROTC has been well above 10%.

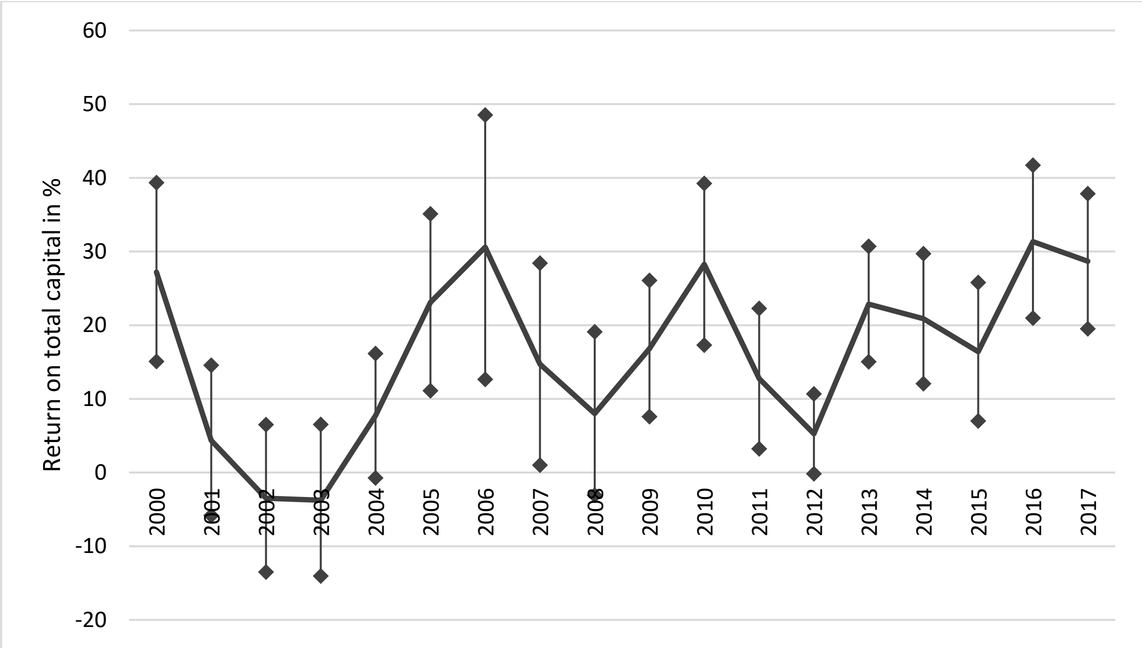

Figure 6. Average and st.dev. of return of total capital (ROTC) of Norwegian salmon firms. Vertical lines represent +/– one st.dev. Data source: Norwegian Directorate of Fisheries[4]

3.4.3. Variation in productive and economic/financial performance across firms

We have observed variation over time and across firms each year in the preceding sections. A question is if the differences in productive and economic performance across firms each year is fairly stable over time, i.e. that there may be fairly stable relative Ricardian rents across firms. In order to investigate this we plot productivity and economic performance metrics for individual firms. We have done this for a subsample of 49 firms which are observed every year from 2009 to 2017. In Appendix A we plot for each firm an individual plot of (a) production per tonne of maximum allowable biomass (MAB), (b) production costs per kg, and (c) return on total capital (ROTC). Furthermore, we plot the ranking of the firm for each of the metrics (a)–(c). The overall picture that emerges is one of significant instability in productive and economic performance for each firm over time. Moreover, the time pattern of variation differs significantly across firms, indicating that they are subject to individual shocks to their productivity and economic performance at different points in time. From the figures A2, A4 and A6 we see that the firms' ranking is unstable. It should also be noted that since we have omitted firms that are not observed all years 2009–2017 from this

[4] See also studies on the relevance of accounting information in the salmon sector (e.g. Misund, 2016, Misund, 2017, Misund, 2018; Asche and Misund, 2016; Misund and Nygård, 2018).

descriptive analysis, and some of these may have exited due to poor economic performance, we may underestimate the volatility of firms' relative performance. However, the implication is that we do not have relatively stable rents as in the Ricardian textbook examples. This is an industry with inherent biological shocks, and other shocks, which leads to large shifts in firms' relative productive and profit performance ranking.

3.5. Concluding remarks

Salmon aquaculture is a sector with significant biological and environmental challenges in the form of e.g. diseases, parasites and escapees. Externalities operate both within the salmon aquaculture sector, but also to other economic agents. Through its history the salmon sector has shown an ability to mitigate externalities through many types of innovations, biological, technological, and organizational. There are opportunities for sustainable growth through innovations and investment in the coastal zone, on land and offshore. This requires an appropriate and difficult balancing act between different sustainability concerns. The future tax regime may play an important role, where the design will influence the opportunities for sustainable growth through incentive and disincentives. It is necessary to analyze a broad menu of tax alternative – on profit, revenue, environmental emissions etc. Government also needs to balance its aquaculture growth objectives vs tax regime and tax revenue in the short and long run. Our estimates on the effects of a proposed resource rent tax suggest that there are policy goal conflicts between growth and tax revenue considerations.

3.6. Acknowledgments

First of all we would like to thank the Research Council Norway (grant no. 283312) and Fiskeri- og Havbruksnæringens Forskningsfinansiering (grant no. 901526) for funding our research on aquaculture taxation.

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3.8. Appendix A: Development of productivity and economic performance over time at the firm level

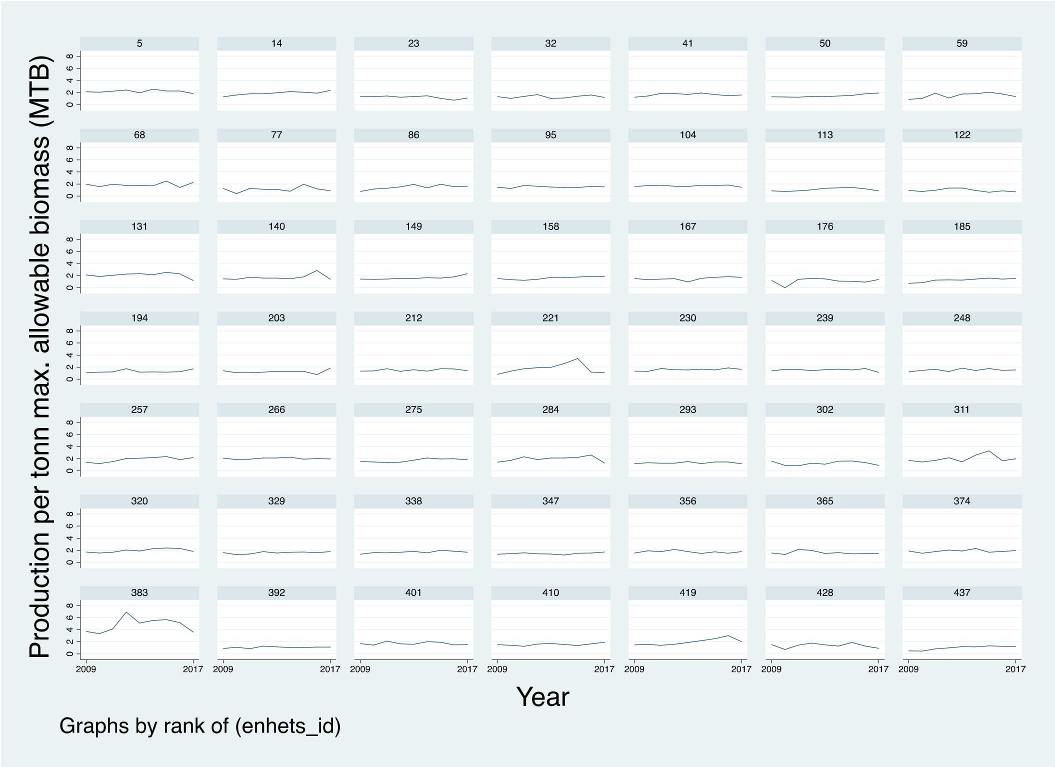


Figure A1. Production per tonne maximum allowable biomass for 49 firms observed 2009–2017. Data source: Norwegian Directorate of Fisheries.

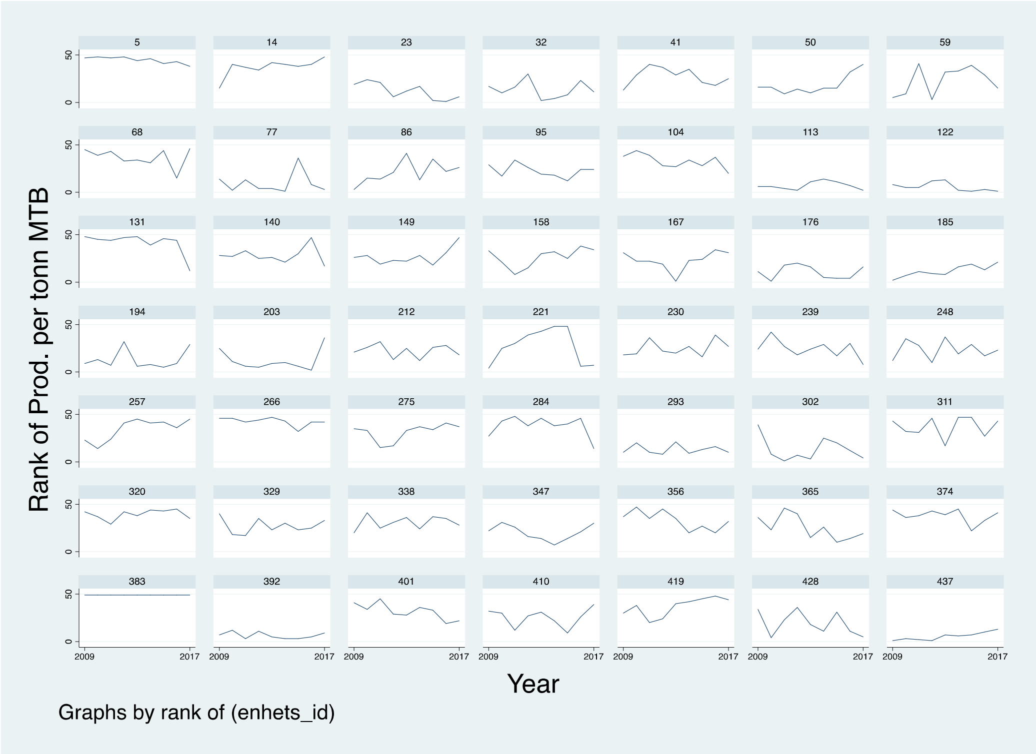


Figure A2. Firm ranking by production per tonne maximum allowable biomass for 49 firms observed 2009–2017. Data source: Norwegian Directorate of Fisheries.

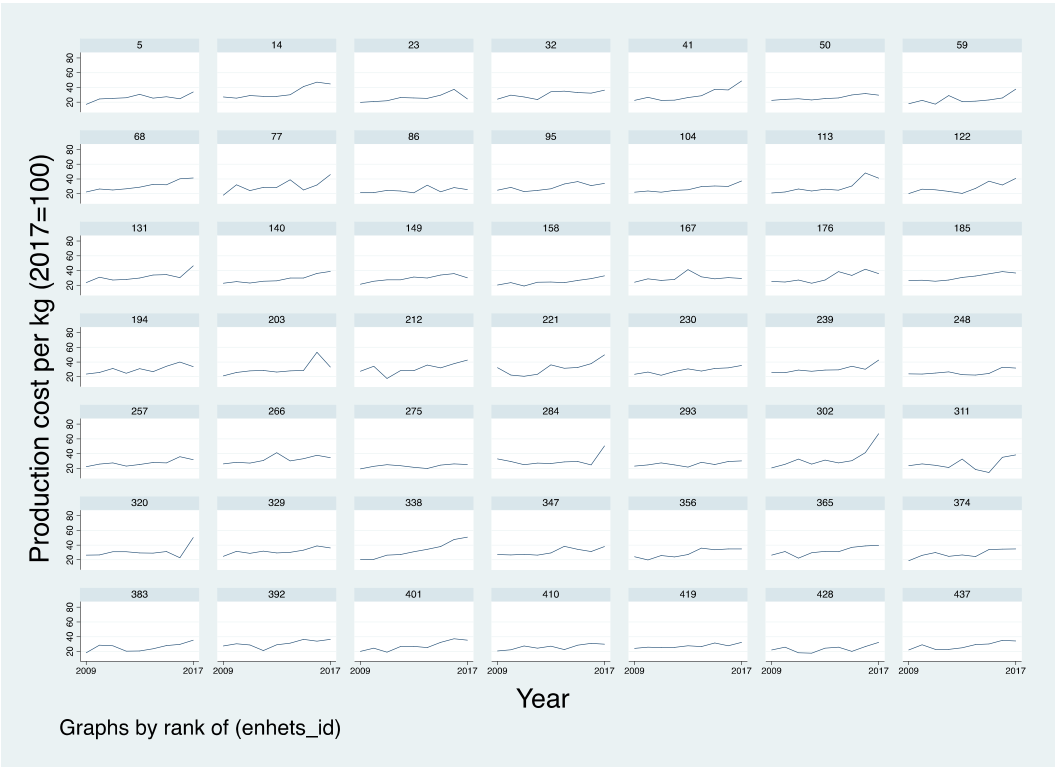


Figure A3. Production cost per kg for 49 firms observed 2009–2017. Data source: Norwegian Directorate of Fisheries.

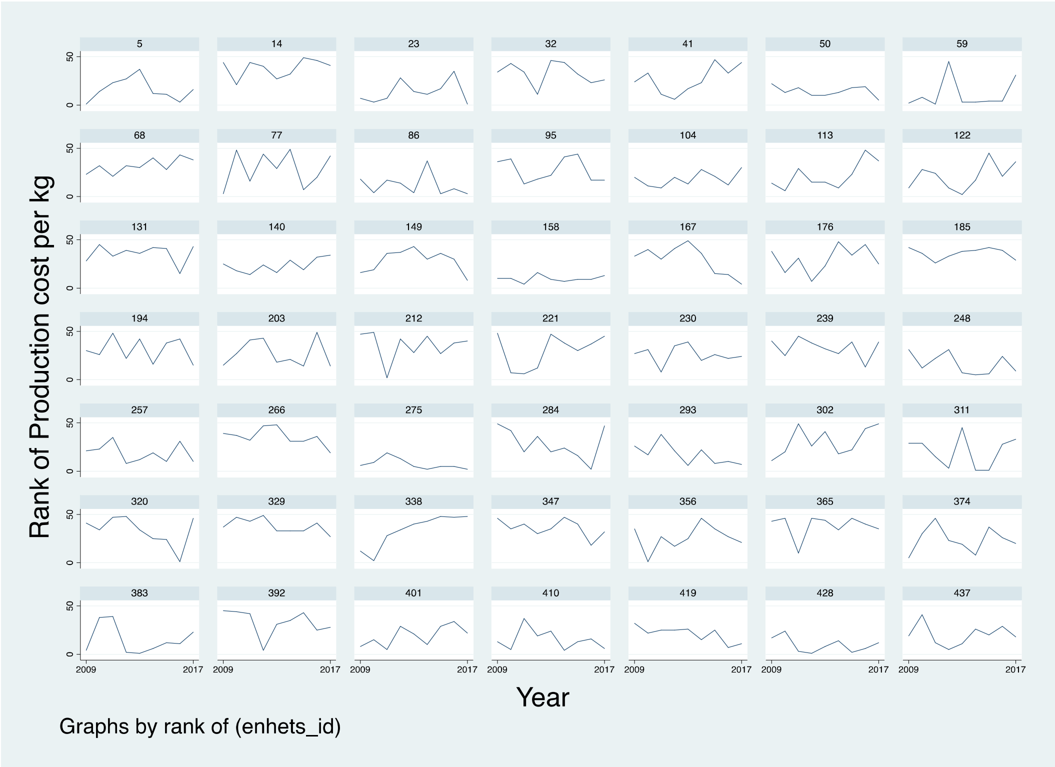


Figure A4. Firm ranking by production cost per kg for 49 firms observed 2009–2017. Data source: Norwegian Directorate of Fisheries.

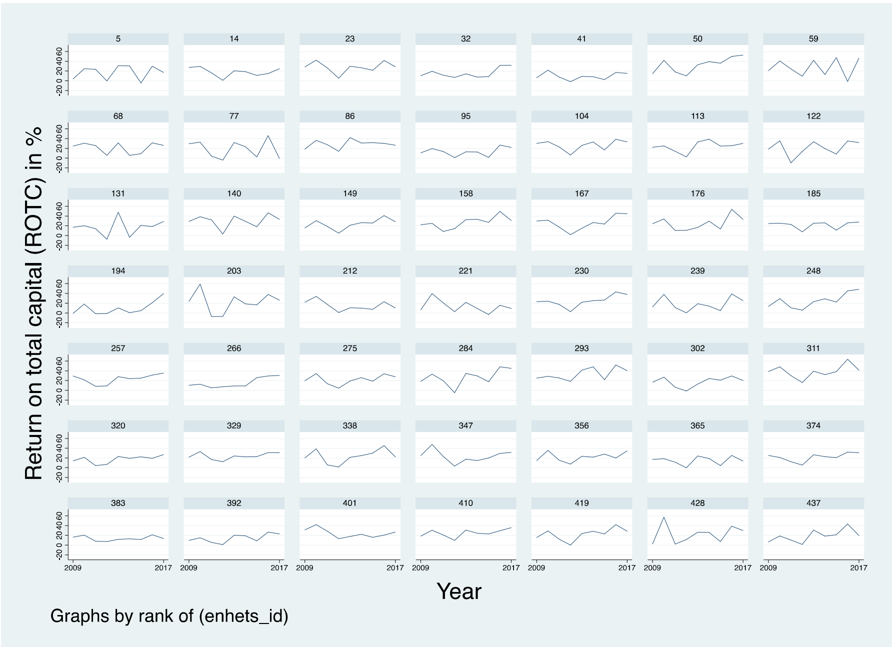


Figure A5. Return on total capital (ROTC) for 49 firms observed 2009–2017. Data source: Norwegian Directorate of Fisheries.

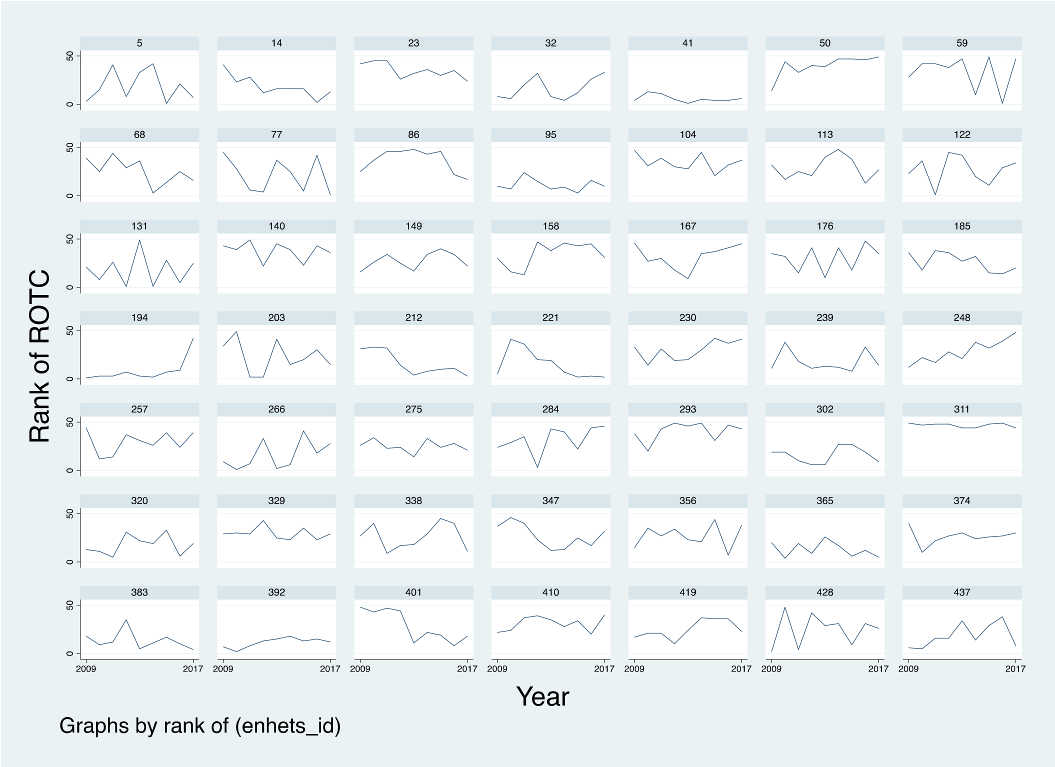


Figure A6. Firm ranking by return on total capital (ROTC) for 49 firms observed 2009–2017. Data source: Norwegian Directorate of Fisheries.

4. Paper 3 «Economic rents in salmon aquaculture»

4.1. Abstract

In recent years, the Norwegian salmon aquaculture industry has generated substantial extraordinary profits, and market values of farming licences have soared, suggesting that the industry is generating substantial economic rents. Yet very little is known about the nature of economic rents created in salmon aquaculture. The rents may be a manifestation of scarce resources, such as limited access to suitable production sites or farming licences. Alternatively, there could be regulation rents due to environmental regulation, or possibly persistent inframarginal rents due to heterogeneity in skills and efficiencies amongst producers. The purpose of this paper is two-fold. First, we examine the nature of economic rents in Norwegian salmon aquaculture, and in the second part we estimate the size of the rents. We estimate the size and time variation of total, inframarginal and regulation rents using data from Norwegian salmon farmers from 2000 to 2020. Since 2015, economic rent has increased substantially compared to the 2000s, coinciding with more stringent environmental regulation. Our analysis suggests that economic rents in salmon aquaculture are dominated by inframarginal, rather than classical scarcity or resource rents. The latter a result of increased cost heterogeneity, partly explained by more stringent environmental regulation and increased sea lice treatment costs. In the last 10–20 years, the motivation for regulation has shifted from fear of overproduction and subsequent dumping and subsidy allegations to motivation grounded in environmental and biohazard concerns. Combined with demand growth, imperfect environmental regulation can result in an environmental regulation rent. Our study contributes to an increasing literature in fisheries and aquaculture on inframarginal rents and increases our knowledge on rent generation and dissipation in salmon aquaculture.

4.2. Introduction

In recent years, Norwegian salmon aquaculture has generated high extraordinary profits (Asche, Cojocaru and Sikveland, 2018; Asche, Sikveland and Zhang, 2018; Misund and Nygård, 2018; Sikveland, Tveterås and Zhang, 2021). High profit margins as well as escalating market values of farming licenses, suggest the presence of economic rents. However, the type of economic rent in salmon aquaculture is still unexplored territory in the literature. Economic rents can come in many forms, such as scarcity, regulatory, inframarginal rents, investment, monopoly, political, market power, quasi rents etc. (Schwerhoff et al., 2020). Correct classification of the economic rents in salmon aquaculture is important for several reason. Firstly, some types of rents reflect inefficiencies and should be minimized. An example is economic rents that arise from some activity that causes harm to the environment. Second, other types of rents are good candidates for rent taxation and could be taxed using neutral taxes without causing distortions and welfare losses. Third, some types of rents reward investments and should be supported. Understanding the type of rent and its source is therefore essential for devising policies that promote efficiency gains and distribution without resulting in welfare losses or negative environmental effects.

In this paper we examine the types of rent that can be present in salmon aquaculture. Using the framework of Schwerhoff et al., (2020), rents are broadly attributed to three types; i) absolute rents (scarcity rent, regulation rent etc.), ii) inframarginal rents and iv) quasi rents. This framework is in line with a definition of rents typically found in the fisheries economics literature, where total economic rent is said to consist of resource rent, inframarginal and quasi rents (see e.g. Coglan and Pascoe, 1999). We discuss the sources of scarcity that can result in rents in the Norwegian salmon aquaculture industry. Our analysis suggests that regulation of licences and production sites are the main sources of scarcity in salmon aquaculture, and therefore important for rent generation. The economic rent in aquaculture is therefore appropriately referred to as regulation rent. Moreover, substantial, and increasing cost heterogeneity suggests that a proportion of total rent are inframarginal rents. Looking more closely at the motivation behind regulations, there seems to have been a paradigm shift in the type of aquaculture regulation. Until the 2000s licence regulations were motivated by authorities' concerns for dumping and subsidy allegations in major consumer markets, while over the last 10–20 years regulation has shifted and become primarily motivated out of concerns for the industry's environmental impact. Hence, the regulation rent has gone from a market regulation rent to an environmental regulation rent. This finding should have important implications for rent capture design. While capture of market regulation rent can be justified as a transfer of rent to the public, this is not the case with environmental regulation rents (Oglend and Soini, 2020; Schwerhoff et a., 2020). In the latter case, taxation should be motivated by correcting the market failures behind the creation of environmental regulation rent. A Pigouvian tax will be more appropriate than rent taxes since the former will tax the source of pollution and therefore a more efficient way of regulating negative externalities. Since economic rent in aquaculture consists of different types of rent, design of rent capture mechanisms in salmon aquaculture must be considered carefully by the social planner.

In the second part, we estimate the economic rents in the salmon aquaculture industry 2000–2020, both total economic rents, as well as inframarginal rent. Here we draw on insights from the fisheries economics literature. There is a substantial literature on rent classification, creation, capture, and dissipation in fisheries and other resource industries (Copes, 1972; Coglan and Pascoe, 1999; Flaaten et al., 2017; Greaker et al., 2017; Arnason et al., 2018; Jensen et al., 2019; Asche et al., 2021). In 1954 H. Scott Gordon published his seminal work on fisheries economics titled “Economic Theory of a Common Property Resource: The Fishery” (Gordon, 1954). Gordon’s model describes rent creation and dissipation in a resource-based industry. In an open access fishery, there are no entry restrictions, and the individual vessel has an incentive to increase fishing effort until profits are zero. The individual fisherman does not take into account the impact of her increased fishing effort on the reduction in profit for the fishery as a whole. This is an example of tragedy of the commons, and the result is that the total revenues equal the total costs for the fishery, and no economic rent is generated (rent dissipation). Economic rent can only be created at lower fishing effort levels. This rent is called resource rent in the fisheries and resource economics literatures and reflects the value of the fish in the sea (i.e. the cost of the input generated by the fish stock). Effective fisheries management is one approach that can achieve this, and the resource rent is for this reason sometimes called a management rent (Anderson, 1989). Each vessel would receive a profit equal to the vessels share of the resource rent. At some level of fishing effort, the resource rent is maximised. An economic aim of fishery regulation is to avoid excessive fishing effort and thereby facilitate resource rent creation.

In Gordon’s model a homogenous cost structure is assumed, and in an open-access fishery the resource rent will dissipate and in the zero-profit case, making the value of the fish become worthless. However, as Jensen et al., (2019) point out, the resource rent is only exhausted for the marginal vessel, while the inframarginal vessels can still receive rent. While in Gordon’s model all vessels are marginal, Copes (1972) argues that “rents yielded by fishing activity include rents to intramarginal inputs of labour and capital, which are not dissipated by unlimited entry to the fisheries.”, suggesting that the distinction between resource rent and inframarginal rent is important one to analyse. According to Coglan and Pascoe (1999) failure to separate economic rents into resource and inframarginal rents may result in a misrepresentation of economic performance in a fishery.

Recent literature suggests that there could be a substantial inframarginal rent in salmon aquaculture (Asche et al., 2020; Arnason and Bjørndal, 2020). While some researchers have estimated the size of total economic rents in salmon aquaculture (Lindholdt and Greaker, 2021) there are no studies examining the nature of economic rent generation in aquaculture. In simple economic models economic rent is generated by the scarcity of a single factor of production. In more advanced models, economic rent can be generated by scarcities in several factors of production (Arnason and Bjørndal, 2020), suggesting the existence of more than one type of economic rent.

Estimation of economic rent is challenging for many reasons. Firstly, economic rent is not the same as economic profit (Arnason, 2011; Arnason et al., 2018; Arnason and Bjørndal, 2020). While financial performance of salmon farming companies can be ascertained using accounting information (Misund, 2017, 2018; Misund and Nygård, 2018), information on the opportunity cost of capital is missing, a crucial input for calculation of economic profit. Depending on the curvature of the profit function, economic rent can be higher or lower than economic profit. Second, economic rent is not the same as consumer surplus, since the latter is the revenues less the variable costs, while rent also considers the opportunity costs of all inputs (Varian, 2016). Moreover, separating resource rent from inframarginal rent is important, but challenging since its calculation requires estimation of the marginal cost curve. Inframarginal rent can be calculated as the area to the left of the supply curve below the cost of the marginal firm, and below the marginal revenue. Following the approach of Coglan and Pascoe (1999), we estimate industry marginal cost curves for each year 2000–2020 and estimate the size of inframarginal rent. Total economic rent is estimated as the difference between unit marginal revenues and average unit cost, multiplied by the total production, and calculate regulation rent as the difference between total economic and inframarginal rents. Our results show that inframarginal rents has dominated total economic rent in all years except 2010. We also find that total economic rent has increased substantially since 2015. While regulation rents were high in 2016 and 2017, this type of rent has since dissipated and been replaced by inframarginal rents. We discuss the possible reasons for this development, including both temporary effects such as currency depreciation, biological problems in Chile, as well as more structural effects as a result of stricter environmental regulation.

The rest of the paper is organised as follows. First, we provide a background for the development in profits in the Norwegian salmon sector, followed by a literature review of the literature of rent theory in the fisheries and resource industries. Then, we discuss the nature of rents in salmon aquaculture and the sources of scarcity that can generate economic rents. In the second part, we empirically estimate total economic, inframarginal and regulation rents. In the final section we conclude and discuss policy implications of our findings.

4.3. Background: The Norwegian salmon aquaculture industry

Salmon farming has been a commercial success since its breakthrough in the late 1960s (Asche and Bjørndal, 2011; Asche, 2008). Between 1970 and 2018, annual global production has on average grown by approximately 21%. In the 1970s, Norway’s production growth was higher than the global average, but since the beginning of the 1980s, Norway’s share of production has fallen, and is currently around 50% (Figure 1).

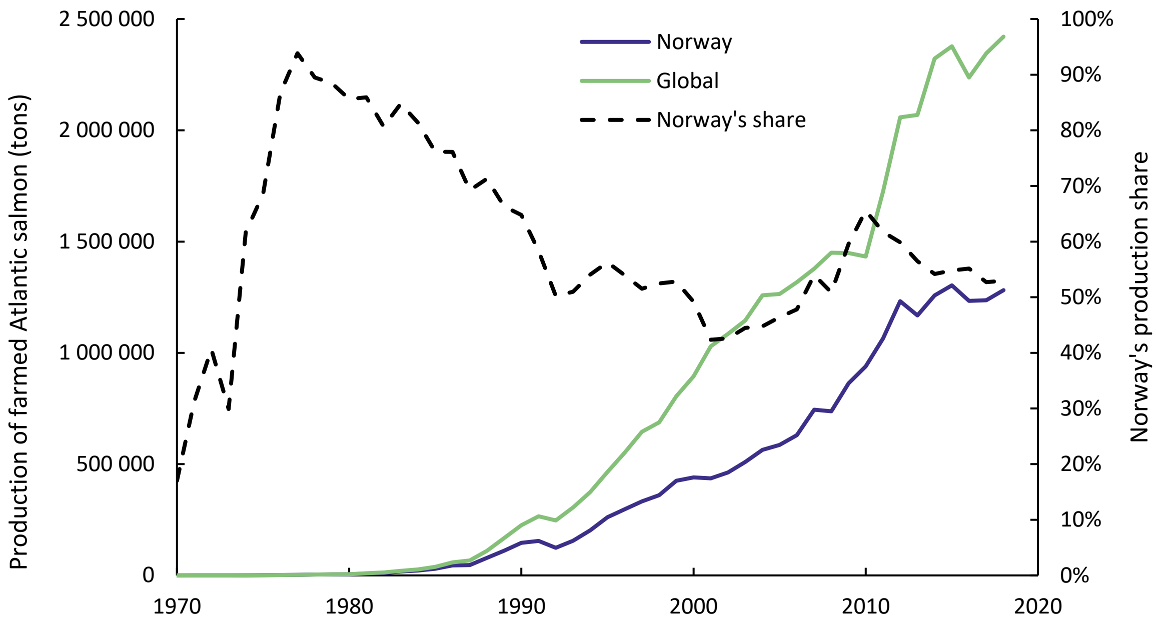


Figure 1. Production of farmed salmon in Norway and globally. Source: FAO.

Until around the turn of the century, productivity growth and innovations resulted in a fall in production costs (Tveterås and Heshmati, 1999; Tveterås, 2002; Asche et al., 2003, 2007; Vassdal and Holst, 2011; Asche et al., 2013; Roll, 2013) and consequently also salmon prices (Figure 2). The industry was characterised by improvements in production techniques, economies of scale, feed quality and nutrition (Asche and Bjørndal, 2011).

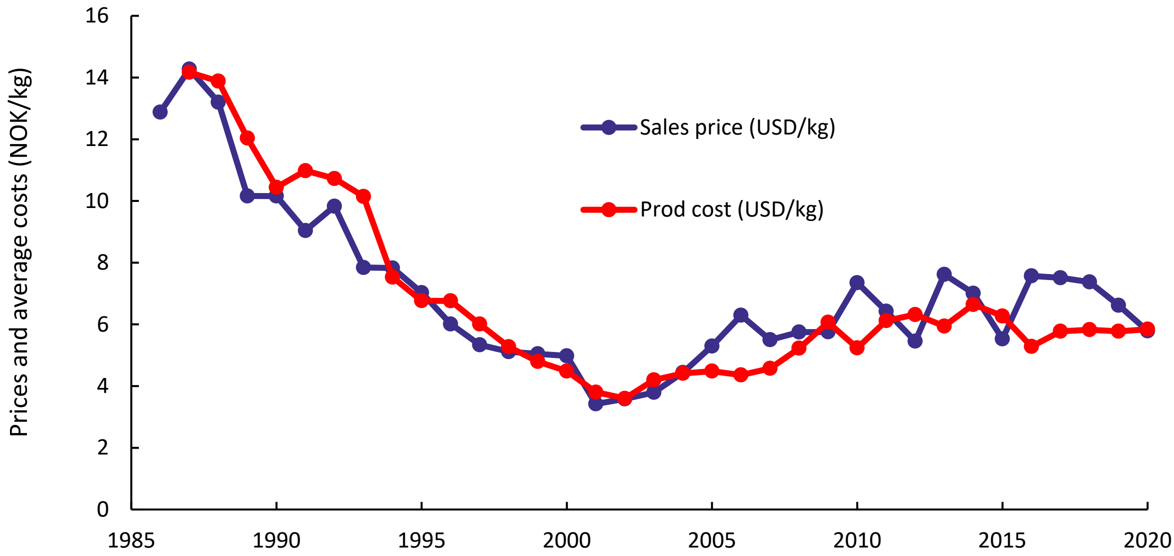


Figure 2. Prices and costs in Norway. Source: The Norwegian Directorate of Fisheries (operating costs) and the authors' own calculations (capital costs). The average costs include capital costs (measured per kilo WFE, based on a cost of capital of 8 percent).

Since then, productivity growth has fallen (Vassdal and Holst, 2011; Asche et al., 2013a; Aponte Rocha, 2020). The main reasons being adverse biological conditions (sea lice), higher input prices and external market situations (Rocha-Aponte and Tveteras, 2019), external factors which are out of the control of the individual producer. However, also internal factors (e.g. stocking of fish) are important as the industry has reached capacity limits (Oglend and Soini, 2020). Production costs have soared in the last decades and doubled since the early 2000s in nominal terms and increased by approximately 65 percent in real prices, measured in Norwegian currency, but the increase has been less measured in USD due to a substantial depreciation of the NOK against the USD since 2013. The main drivers for the increased production costs are labour costs, depreciation, and miscellaneous costs (Iversen et al., 2020), as well as high direct and indirect costs from sea lice infestations (Abolofia et al., 2017; Asche et al., 2021a). The industry has becoming capital intensive in response to the increased problems with sea lice and diseases, as well as investments in smolt facilities and other infrastructure real assets driven by capacity constraints (Blomgren et al., 2019; Misund and Tveterås, 2021).

Meanwhile, increases in demand (see e.g. Brækkan et al., 2014; 2018), combined with stagnated production levels, have resulted in increased price levels over the last decade.

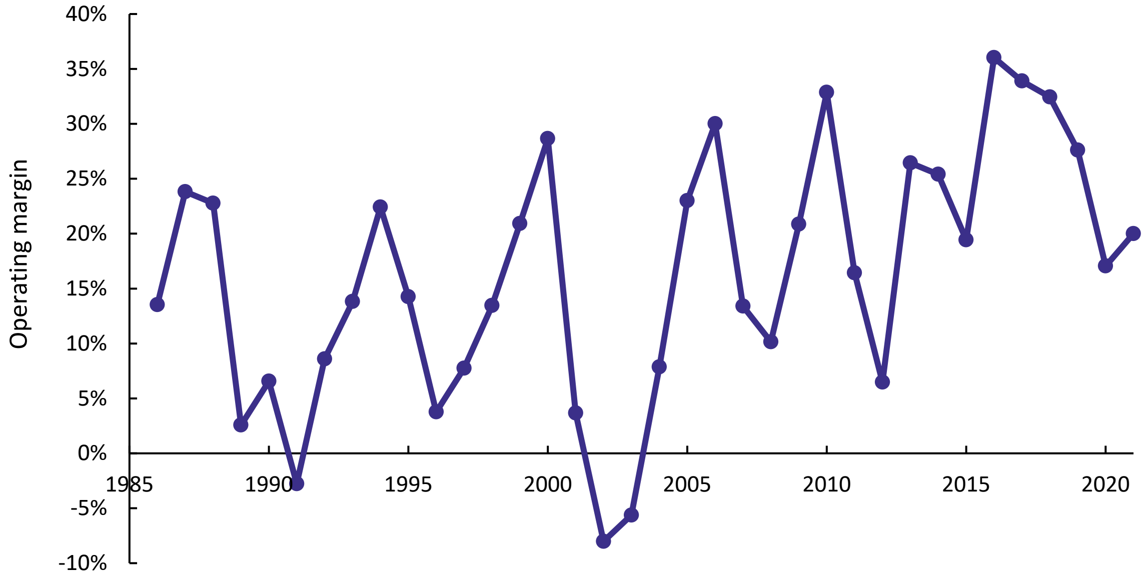


Figure 3. Profit margins in Norwegian salmon aquaculture. Source: The Norwegian Directorate of Fisheries. The operating margin is calculated as the operating profit (before tax) divided by total revenues.

Figure 3 demonstrates the cyclical nature of salmon aquaculture, making calculation of rent challenging[5]. In 2016, the aggregate operating margin was at an all-time high of 36 percent but has since fallen to 17–20 percent in more recent years. The average operating margin between 1986 and 2009 was 14 percent, while this average has increased to 25 percent over the last decade, documenting a general increase in profitability in the last decade compared to earlier years. In addition to higher profit margins, the market value of salmon farming licenses has also increased over the last decade (Asche et al., 2020). A higher level of returns combined with scarcity of some of the input factors of supply, such as licenses and production sites are limited, is a very strong indication of substantial economic rents in Norwegian salmon aquaculture. However, the exact nature of rent generation in salmon aquaculture is not well described in the literature in the same

[5] There are numerous studies in the aquaculture economics literature examining profits and volatility (see e.g. Asche and Oglend, 2016; Asche et al., 2016a, Asche et al., 2016b; Asche et al., 2019; Oglend 2013; Oglend and Sikveland, 2008; Misund 2017, Misund 2018; Misund and Nygård, 2018).

way that Gordon's model has done for fisheries. The next sections in the paper will therefore present relevant rent theory and examine the sources of scarcity in salmon aquaculture in order to determine more precisely the nature of rent generation in this sector.

4.4. Economic rents

Theories of economic rent has a long a complex history and has resulted in a multitude of different definitions of economic rent, definitions which often are study specific. Given the complexity, economic rent is most appropriately considered an umbrella term, consisting of more basic rent types such as regulation rent, inframarginal rent, quasi rents, etc. (Asche et al., 2021b).

4.4.1. Historical development of rent theory

According to Bina (1992), there is no general theory of economic rents. Furthermore, Wessel (1967) asserts that "Although the concept of economic rent has been widely used by professional economists for many years, as yet no clear consensus concerning its meaning exists." The precise definition of economic rent has been a topic for debate in the economic literature for two centuries (Buchanan, 1929; Brown, 1941; Mishan, 1959; Currie et al., 1971; Fine, 1983; Bina, 1992; Schwerhoff et al., 2020), spanning several schools of economic thought. The concept of rent goes back to The Physiocrats (Fine, 1983) and rent theory was further developed by the classical economists such as Thomas Malthus, Adam Smith, and Mills (Fine, 1983). Ricardo was the first to develop a clear theory of rent (Ricardo, 1817). Karl Marx extended Ricardo's theory by including the concept of absolute rents (Marx, 1894). Later rent theory also included other types of rents such as inframarginal, entrepreneurial and quasi rents.

Adding to the confusion, the concept of economic rent is defined differently in the economic literature. While early rent theories had very specific definitions of rent in mind, such as Ricardo's land rent, modern economics apply a more general definition of rent. According to Varian (2016) economic rent is "… payments to a factor of production that are in excess of the minimum payment necessary to have it supplied"[6]. Even more general, Arnarson and Bjørndal (2020) define economic rent as "Economic rents are payments (imputed or otherwise) to a variable above the marginal costs of supplying that variable".

There is also disagreement on the temporal aspects of rent. While a factor of supply might be restricted in the short run, in the long-run the supply curve is more elastic. Mishan (1968) even argues that "…. The area above the rising industry supply curve carries no economic significance", while Sheperd (1970) posits that the area above the long-run industry supply curve carries economic significance.

Hence, the concept of rent is dependent on the school of economic thought, as well as the temporal perspective. Rent is typically analysed using partial equilibrium settings, and not in a general equilibrium framework.

4.4.2. Rents vs profits

Arnarson (2011) and Arnarson and Bjørndal (2020) point out that economic profits and rents are not the same concept, depending on the presence of fixed costs and shape of the profit function. In the most plausible case of positive fixed costs and strictly concave profit function, the relationship between profits and rents are indeterminate. Variable profits, on the other hand, will always be higher than or equal to rents given an at least weakly concave profit function. Furthermore, accounting profits are not an accurate representation of neither economic profits nor rents. Financial accounting is innately conservative, and assets are recorded at historical costs, and do not reflect their market values (Harris and Ohlson, 1987; 1990). Moreover, economic profits and rents are based on the alternative costs of labour, capital etc., while accounting profits are based on recorded and historical costs. Additionally, capital costs are not fully reflected in accounting profits. While net profits are net of payments in debt, equity cost of capital are never included. Using

[6] Wessel (1967) attributes the differences in definitions to two distinct rent theory schools, Ricardian and Paretian, but later researchers disagree with this interpretation (see e.g. Lipman and Rumelt, 2003).

accounting profits as a proxy for economic profit or rents will potentially lead to an overestimation unless the costs are adjusted to reflect their alternative use value.

4.4.3. Policy implications of rents

High extraordinary profits suggest the existence of economic rents in the Norwegian salmon aquaculture industry. To a social planner, the source of the rent is of substantial interest, as this will have consequences for choice of rent capture mechanisms. If the economic rent is generated by scarcity, e.g. due to boundaries defined by nature, society could benefit from a transfer of portion of this rent using some sort of rent taxation. If the economic rent arises from environmental regulations, then Pigouvian taxes are more relevant as it allows the society to improve economic efficiency, since the distorting tax will result in polluting firms internalising externalities and thereby taking into account also the costs for society of their activity.

Other rents, such as investment rents, entrepreneurial rents, and skipper rents should be supported since they may improve innovation by allowing for returns to talent. These types of rents will arise from cost heterogeneity and are included in the concept of inframarginal rent. Sometimes they are also considered part of normal profits. Taxation of inframarginal rents is therefore challenging as it will reduce returns to talent (Johnson, 1995).

4.4.4. Taxonomy of rents

In a simple model, with one factor of supply which is fixed, the economic rent attributed to that factor of supply, and is called pure economic rent, and is shown by the dark grey area in Figure 4.

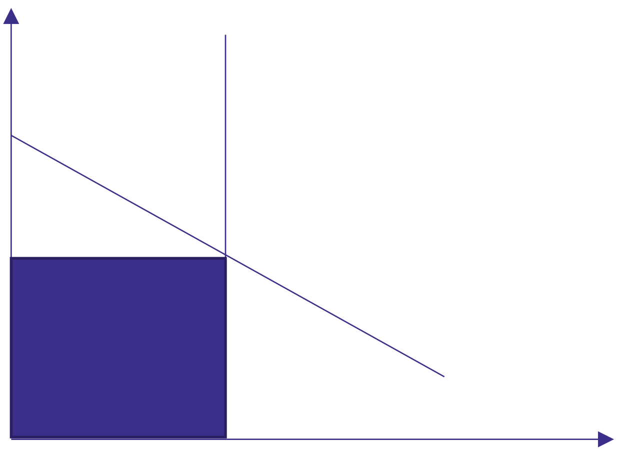


Figure 4. Pure economic rent

The representation of rent in Figure 4 is too simple for most analytical purposes. Firstly, for most industries the profit function will be based on several input factors which each could generate a rent if in limited supply. Second, industry marginal cost curves are often upward sloping generating a different type(s) of rent, than if the supply curve is bounded due to a single fixed factor of supply. Secondly, the elasticities of the long-run supply curve could be higher than that of the short-run, making some of the rents temporary. A more realistic description is a discontinuous supply curve combining both an upward sloping part reflecting that the cost of production in an increasing function of quantity produced, and that the supply is bounded at some quantity, where the demand at the maximum quantity determines the price, which is higher than the marginal cost of the highest cost producer.

However, in salmon aquaculture, as in many commodity industries, there will be many input factors in the profit function (see Eq. 1), all of which can be fixed in supply in the short or longer term (Arnarson and Bjørndal, 2020).

In this setting, economic rents, R, can be expressed as:

$$R(q, \boldsymbol{z}) = \Pi_q(q, \boldsymbol{z}) \cdot q \qquad (1)$$

where $\Pi_q(q, \boldsymbol{z})$ is the marginal profit function for variable q. The vector **z** denotes all the other variables that determine profits, such as technology, labour, capital, entrepreneurship, etc. variable q's marginal profits. Hence, the total economic rents are very difficult to attribute to any single one of these variables (Arnarson and Bjørndal, 2020).

Instead of trying to isolate all possible types and sources of rent, it is more analytically tractable to identify broader groups of rents. Typically, resource economists refer to three types of rents; scarcity/resource, inframarginal, and quasi rents (Jensen et al., 2019; Gochberg and Menaldo, 2020). These rents can be analysed in the context of partial equilibrium (Figure 5), and which can also incorporate discontinuous supply curves mentioned above (see e.g. scarcity rent in Table 1).

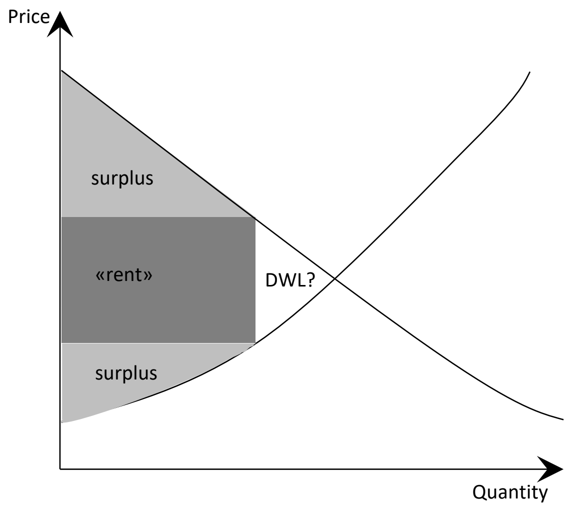
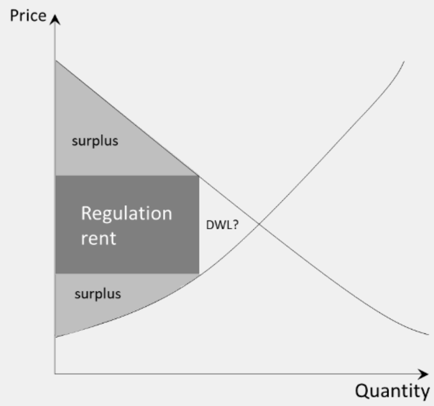
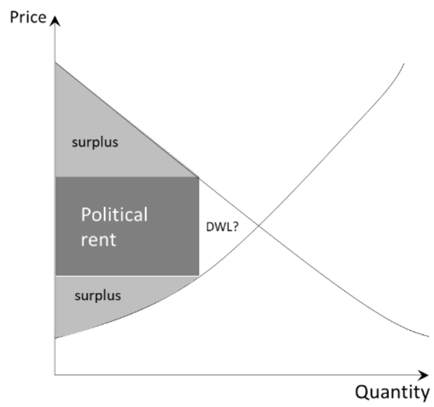
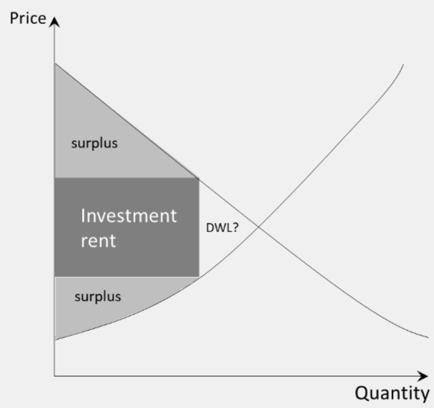
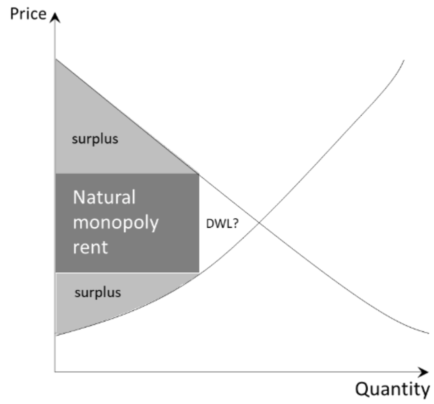
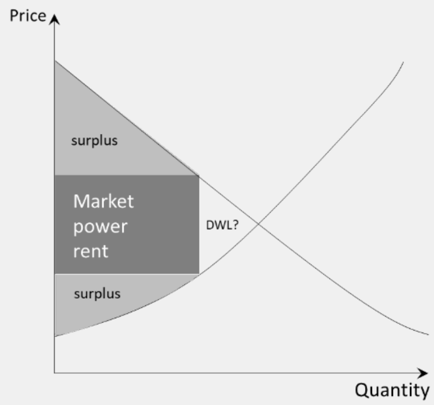
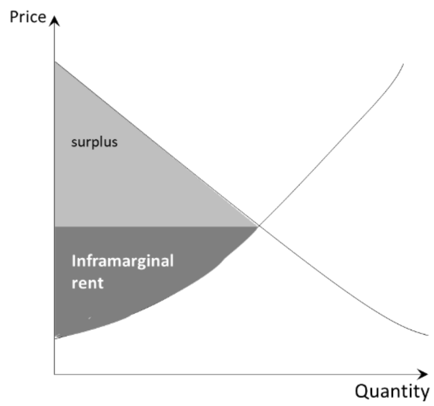


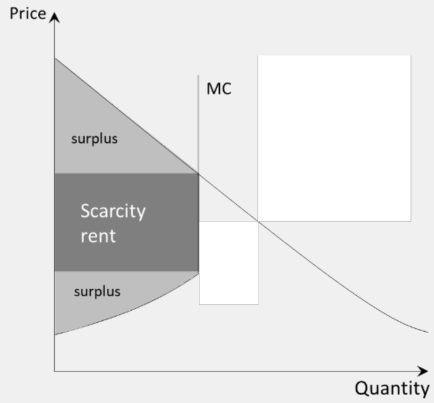
Figure 5. Partial equilibrium model

Schwerhoff et al., (2020) group rents into seven categories, such as regulation, political, market power, natural resource, scarcity, natural monopoly and inframarginal rents. In addition, some goods may also generate quasi rents in the short run. Table 1 explains the differences between these types of rent in the context of a partial equilibrium model.

Table 1. Seven categories of economic rent according to Schwerhoff et al., (2020), plus quasi rent.

Type of rent	Definition	Figure
Regulation rents	Some goods can cause an externality and create a wedge between the private and social marginal costs of production. Governments can use regulations to correct this type of market failure.	
Political rents	Rents created intentionally by politicians. These rents are tolerated and often created to improve profits.	
Investment rents	Rents that are a result of private investments (innovations) that can generate market power.	

Natural monopolies	Barriers to market entry, such as high fixed costs.	
Market power	Market concentration (network effects and aggressive anticompetitive behaviour by some firms). In some exhaustible resource industries, the economic rent will be market power rent rather than a scarcity("resource") rent. Technological advances allow for more efficient extraction of the resource.	
Inframarginal rent	A result of a convex production technology. Similarities with Ricardian land rent and Marx' differential rent I.	

<table>
<tr>
<td>Scarcity rents</td>
<td>The supply curve will be below demand since the resource is in finite supply. Equilibrium price is higher than the marginal cost of production, generating a scarcity rent.</td>
<td>
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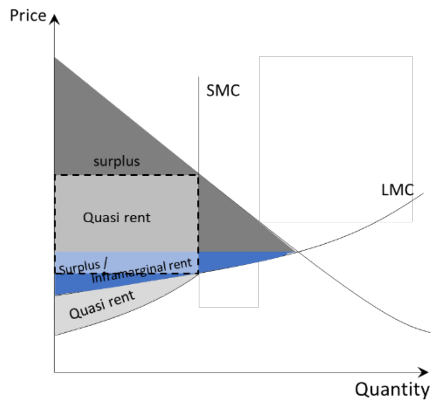
<tr>
<td>Quasi rent</td>
<td>A type of temporary “economic rent”. Generated when a resource is unresponsive to price for a short time interval. The rent does not affect the current supply but will affect the future supply[7].</td>
<td>
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We see that several of these types of rents resemble each other, such as regulation, political, investment, market power, natural monopoly, and scarcity rents. They are found in the dark grey rectangle. In the fisheries or resource economics literature, these rents are often referred to using the catch-all phrase “resource” rents. We see from Table 1 that the two other rents, quasi and inframarginal, are different in nature from the “resource” rents. Analyses of resource rents often ignore inframarginal rents or quasi rents, possibly overestimating the size of the “resource” rent. It is therefore meaningful to categorize rents into the three broad groups mentioned above, namely “resource” rents plus inframarginal and quasi rents, before. However, for purposes of social planning (e.g. policy design) or analysing the impact of policy (e.g. rent taxation), a more careful examination and classification of the type of rent(s) present is prudent, especially if rents arise from market failure, e.g. due to negative externalities. In this paper, the aim is to examine the size and

[7] As defined by Alchian (1987).

determinants of inframarginal rents, so the composition of the “resource” rent is of lesser importance.

However, the literature on economic rents in aquaculture is very thin, and the topic therefore deserves some attention. We will therefore, before carrying out the empirical analysis, first examine the qualitative nature of rents in salmon aquaculture. We draw on the fisheries and other resource industries literature in our synthesis of rents in aquaculture. In fisheries, regulation serves several purposes. Firstly, an essential aim of fisheries management is to avoid the tragedy of the commons. The quantity produced is less than the equilibrium quantity given open access to the resource, and results in a regulation rent. A second purpose of regulation is to increase profitability in the sector and is often used as a political tool to improve rural economies. This introduces an element of political rents. Furthermore, other types of rents such as investment rents and market power rents could also be present. This is especially the case in petroleum extraction, often referred to a classic case of resource rent arising from a scarce resource, i.e. a scarcity rent. The literature, however, suggests that petroleum extraction and production instead give rise to a market power rent (Hansen and Lindholt, 2008; Huppman and Holz, 2012; Nakov and Nuno, 2013), and political rents (Schwerhoff et al., 2020), but not scarcity rents (Hamilton, 2009; Hart and Spiro, 2011; Cairns and Calfucura, 2012). The reason is that for many nonrenewable resources, the amount of the resource is sufficient to for maintaining the current level of consumption (Krautkraemer, 1998). An important cause is that technological innovations will make more of the resources available for extraction and production (Hart, 2016).

Hence, the term “resource rent” is therefore a generic definition of the rents covering regulation, political, investment, market power, scarcity, natural monopoly rents, and is found in the rectangle BCDE in Figure 6. Inframarginal rents is also a generic term incorporating land rent, differential rent etc. (caused by differences in efficiencies and qualities) and captured by the area ABE. Quasi rents could also be present and can be part of both resource and inframarginal rents. These three groups of rents are aligned with those described in Jensen et al., (2019), except that the authors refer to resource rent as a scarcity rent, while our definition includes scarcity rents along with regulation rent, market power rents etc.

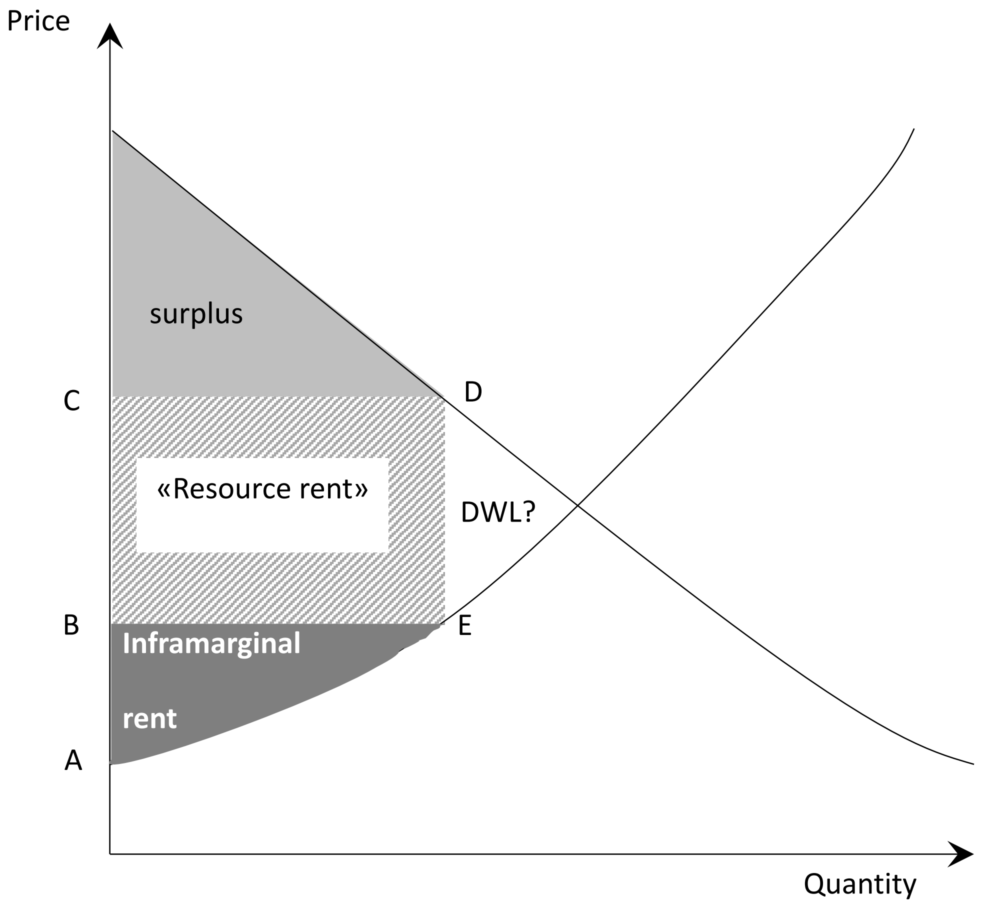

Figure 6. "Resource" and inframarginal rents. Based on Schwerhoff et al., (2020).

4.5. Potential sources of rents in Norwegian salmon aquaculture

In the following, we will examine the sources of the economic rent in Norwegian salmon aquaculture on a conceptual level.

4.5.1. Regulation, resource or scarcity rent?

The Norwegian salmon farming industry is regulated, but the regulation has struggled to keep up with the industry's development over time (Hersoug, 2021). The regulatory system has often been changed as a response to changes in the industry's challenges and changing public concerns (Young et al., 2019). In the 1980s the size of sea pens was limited to restrict the production of salmon out of concerns for the adverse effects of oversupply in the markets. The reason was fear of subsidy allegations and antidumping legislation. Likewise, in the 1990s, the production was also limited with feed quotas for the same reason. Disease outbreaks have also had an important impact, due to substantial bacterial and viral epidemics in the 1970s, 1980s and 1990s. In 2005, the current maximum allowable biomass (MAB) regime was introduced. According to the MAB system, salmon farmers have maximum limits on how much salmon biomass they can have at both the site and the company level. This is not a direct restriction on annual production, but rather limits on the biomass of salmon, measured in metric tons (not the number of individuals), that the firms are allowed to have in their sea pens at any point in time. In the recent decades, sustainability has increasingly become a part of the current regulation.

Similar concerns are found also in other aquaculture countries and for other aquaculture species (Anderson et al., 2019). Concerns about the environmental impact of aquaculture is a main driver for policies and regulations that have hampered the development and success of aquaculture in the European Union (Lasner et al., 2017) and the US (Knapp and Rubino, 2016). In some areas in northern America, commercial farming of finfish and in particular salmon has been banned (Anderson et al., 2019). Recently, Canada banned open sea pen-based salmon aquaculture in British Columbia[8].

Table 2 lists salmon aquaculture regulations by year, type of regulation and also by motivation for the legislation. While environmental concerns have long been part of the aquaculture legislation, its importance has increased over time. As Table 2 shows, regulation until the 2000s was primarily concerned with avoiding overproduction. In the decades before the mid-2000s, Norwegian aquaculture witnessed substantial productivity growth, cost reductions and outwards shifts in the supply curve. Norway was at the time the lowest cost producer and were frequently subject to dumping and subsidy accusations (Asche, 1997; Asche, 2001; Asche and Steen, 2006), often leading to anti-dumping legislation, both in EU and the US.

[8] https://salmonbusiness.com/canada-says-its-taking-the-next-step-towards-transitioning-open-net-pens-in-coastal-b-c-waters/

Table 2. Source: Hersoug (2021) and official legislation.

Year	Regulation	Type of regulation	Primary motivation
1973	License regime	Net pen volume	Fear of overproduction
1991	Fish density	Biomass per cubic metre	Fish welfare / biohazard
1996	Feed quotas	Amount of feed	Fear of overproduction
1998	Operational plans and reporting	Farmers need to submit 2-year plans, and subject to requirements for number of fish, biomass, fish density, feed use, escapees, sea lice counts, use of chemicals etc. Requirements for fallowing between production cycles.	Mixed. Some requirements are motivated by environmental concerns (e.g. sea lice, fallowing, escapees)
2005	Requirements for surveillance of environmental impact from aquaculture	Maximum requirements for adverse impact on sea bed chemistry and biology	Environmental concerns
2005	MAB	Set standards for size (biomass) of licenses. Standard license = 780 tons biomass	Mixed: Biomass restrictions due to fear of overproduction, and dimensioned according to the environmental carrying capacity of the production site.
2008	Lice counts	Maximum levels of sea lice	Environmental concerns

2008	Distance between sites	Minimum 2.5 or 5 km distance between farms	Biohazard (environment)
2009	Lice counts (change 1)	Maximum levels of sea lice	Environmental concerns
2012	Requirements for technical standards of sea pens	Minimum technical standards	Environmental concerns
2013	Lice counts (change 2)	Maximum levels of sea lice	Environmental concerns
2013	Green licenses	Augmented MAB	Environmental concerns
2015	Removal of escapees from rivers		Environmental concerns
2017	Lice counts (change 3)	Maximum levels of sea lice	Environmental concerns
2017	Traffic light system	Augmented MAB	Environmental concerns
2017	Development licenses	MAB	Environmental concerns

While environmental impact has long been part of the regulation system, only in the recent decades have environmental concerns resulted in explicit environmental legislation. The focus of regulation shifted during the 2000s, from trying to avoid overproduction to reducing the negative externalities of salmon aquaculture. In 2012, the Auditor General of Norway published a report criticizing the lack of environmental regulation of the industry. A few years later, the government issued a white paper outlining the future environmentally sustainable regulation of the industry. Concurrently, a series of new legislations were implemented with the purpose of controlling/reducing the negative environmental footprints of the industry, such as sea lice, fish diseases and escapees.

Today, one of the most important regulations is the traffic light system (TLS), which was implemented in 2017. This system regulates the growth in MAB as function of the amount of sea lice on wild salmonids. The Norwegian coast is divided into 13 production regions, and each region is biannually given a colour coding depending on the amount of sea lice on wild salmonids. Red = reduce MAB by 6%, green = increase MAB by 6%, and yellow = no change. Moreover, other rules regulating the industry's impact on the environment, such as sea lice counts, are also in place.

It is important to point out that the MAB system does not regulate *production*, but rather *biomass*, which is different from production (Hersoug, 2021). Production and biomass are different types of variables, the former is a flow variable, and the latter is a stock variable. It is possible to produce quantities which are higher than the requirements for standing biomass, and currently the ration is approximately 1.5:1 in aggregate. We will see later that some companies can produce more than twice their allocated MAB capacity. With further optimization, such as larger fish or putting smolts to sea more frequently, production could increase even further. In practice, several constraints, biological, technological and regulatory, will put a limit on the amount of fish per licence. Figure 7 shows that the production per license increased until 2012 and has since stagnated. However, technological innovations that reduce the externalities could allow for an increase in production per license.

Moreover, as figure 7 shows, the number of commercial licenses does not seem to have stagnated, while the number of production sites has. However, there is there is substantial unused capacity among farmers. According to Hersoug et al. (2020), national production could increase by a factor of 3.3 if all aquaculture areas were equally intensive.

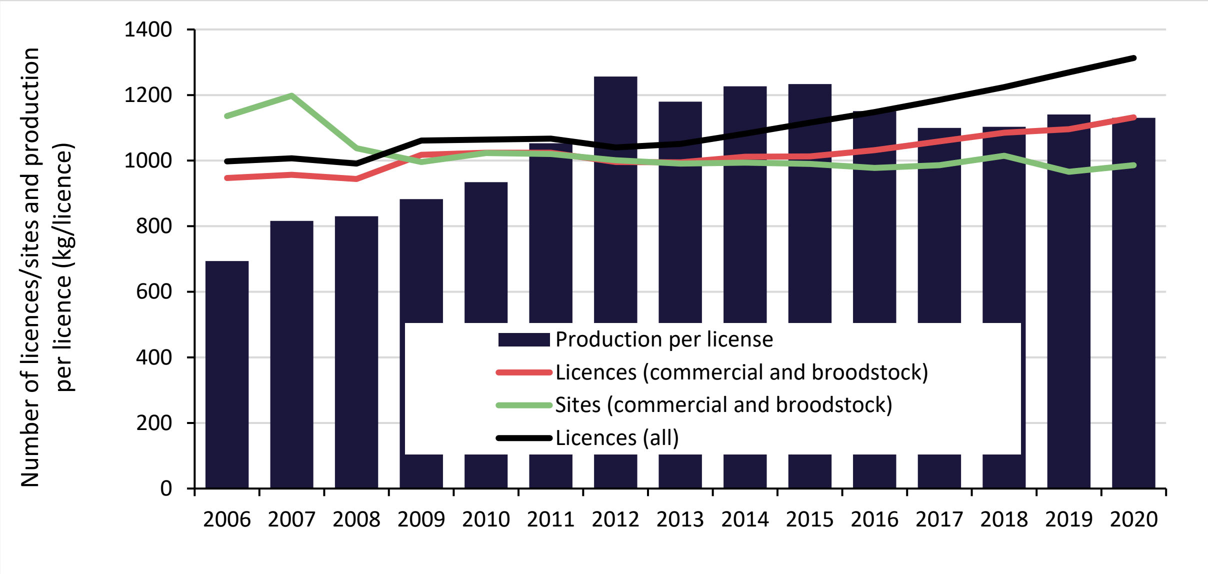

Figure 7. Number of salmon farming licenses and production sites (lines), and production per licence (blue bars), between 1986–2020. Source: The Norwegian Fisheries Directorate.

Economic rent is dependent on the existence of some sort of scarcity. So, what are the sources of scarcity in the salmon industry? The two primary sources of scarcity are licenses and the number of sites (Hersoug et al., 2021). Since the 1970s, the Norwegian aquaculture industry have been regulated by a license system. Aquaculture is prohibited without a license, and the number of licenses is controlled by the Ministry of Fisheries (Hersoug, 2021). An aquaculture license is a form of contract which gives the holder the right to produce salmon or rainbow trout. In addition, there are many other types of regulation that address different aspects of aquaculture production. On the face of it, the potential number of licences are unlimited, and the government could in principle print an infinite number of licences and sell to buyers. Hence, the number of licenses is not constrained by nature, and therefore does not give rise to a resource rent, but rather a regulation rent. As Table 2, and the discussion above, shows, the current regulation is motivated primarily by environmental concerns, and therefore the regulation rent is more correctly referred to as an environmental regulation rent. When the number of licenses were regulated out of fear for dumping and subsidy allegations, this scarcity can generate a market regulation rent. The distinction between an environmental regulation rent and other types of rents is not unimportant, as it will have consequences for choice of rent capture mechanisms.

The second source of scarcity is the number of production sites available for farming. While the number of licenses is not restricted by nature, the number of sites are. A farming license is a pre-requisite for aquaculture activity in Norway, but to start production the farmer also needs one or more production sites. Each site has its own MAB, so there are two levels to the MAB system, one at the license level (license MAB) and one at the site level (site MAB), and they are regulated differently. The License MAB are issued with a standard size (e.g. 780 tonne MAB), but can be increased or decreased [why]. The site MAB, however, is determined by the carrying capacity of the site.

In addition, the number of sites are limited, and in practice the most important restriction of aquaculture today. Limited access to production sistes is often referred to in the extant literature as the “area challenge” of Norwegian aquaculture (Hersoug et al., 2021). For many years, due to the salmon’s strict requirements in terms of water temperature and quality, salmonid farming using open pen technology salmonids was only possible in specific regions globally, such as Norway, Scotland, Ireland, Iceland, the Faeroes, Canada and Chile. Due to the salmon’s specific requirements for temperature, currents, water quality, oxygen content, pollutants etc., one could make the case that nature sets a limit to the number of sites that are available for salmon production, and the economic rent would therefore contain elements of scarcity rents. However, that assumption does not hold for several reasons. First, while there are natural restrictions in some regions, the supply of aquaculture sites in Norway is not restricted from nature’s side, but rather as an effect of regulations (Hersoug et al., 2020). Norway has, through its Exclusive Economic Zone (EEZ), access to nearly one million square kilometer coastal space which in principle could be used for aquaculture. Today’s use is around 59 square kilometers (Hersoug et al., 2020), a use of 0.0059 percent of the total available area. However, various restrictions on distances to other farms, anchoring, etc., the occupied area increases to 125 square kilometers (Menon, 2020) or around 0.01 percent of the total coastal area (or 0.08 percent of the Norwegian territorial waters). However, not all areas are suitable for farming. Moreover, aquaculture competes with other users for the same space, such as fisheries, petroleum activities, maritime, ocean windfarms, military activities, as well as conservation (Hersoug et al., 2020; Menon, 2020). Allocation of new areas to farming will therefore be a trade-off between different interests, and a decision to be made by politicians.

The “area challenge” lies not in a limited number of sites that could potentially be available to farmers. That number is far greater than the number used today. The challenge arises from the restrictions in current environmental and biohazard regulation. According to national guidelines, there is a minimum required distance between fish farms and other fish farms, or other activity of 2.5 to 5 kilometers, depending on size of the fish farm. This minimum distance requirement drastically increases the effective area use of aquaculture. Assuming that there are approximately 1000 production sites, this entails that the effective area use is 19,625–78,000 square kilometers, and 20–80 percent of total coastal zone area. This is a very simplified calculation that does not take into account the structure of the coastline, and that sites are often close to land and therefore includes land area and not sea area. However, the numbers clearly suggests that the effective area use increases drastically when the minimum distances between salmon farms are taken into account. Importantly, environmental and especially biohazard concerns are the main reasons for the very high effective area use. This finding is important for characterizing the type of regulation rent. If the number of sites are limited because the authorities want to generate higher profits for the farmers or out of fear of overproduction, or the result of industry lobbyism for limits to the number of entrants to the industry, then the resulting regulation rent can be taxed using a rent tax without any welfare losses (see e.g. Grafton (1995, 1996) for examples of relevant rent taxes). The same would be the case if the number of sites are limited by nature, i.e. there exist only a limited number of sites which are suitable for salmon farming. In the latter case, this type of scarcity would generate a scarcity or resource rent, similar to the regulation rent in the former case. This type of rent can also be taxed using a rent tax. However, in the case of Norwegian salmon aquaculture, the number of sites is currently not limited by the nature, but by regulation. Moreover, the regulation is motivated out of environmental and biohazard concerns. Hence, the rent is appropriately referred to as environmental regulation rent. The distinction between this type of rent and other types of regulation rent or scarcity rents is important for policy choice, e.g. taxation. While for resource, scarcity or regulation rents (not environmental regulation rent) taxation can be justified on the basis of transfer of rent to the public, this is not the case for environmental regulation rent. Economic tools, such as Pigouvian taxes, that tax the source of the market failure would be more appropriate (Oglend and Soini, 2020; Schwerhoff et al., 2020).

In addition to the general scarcity of production sites, their productivity may also vary (Pincinato et al., 2020), suggesting the existence of a differential or Ricardian rent. In reality, a differential rent would be very difficult to distinguish from other component parts of inframarginal rent. In Ricardian rent theory, differential rent originates from differences in productivity for different plots of land, i.e. resulting in different costs of producing produce on the plots of land, very similar to the inframarginal rent which is caused by cost heterogeneity. However, inframarginal rent is a more modern concept, which encompasses both the classical Ricardian rent / differential rents caused by differences in production site qualities, as well as other causes of cost heterogeneity such as skill (ref), entrepreneurship (ref), quasi rents, as will be discussed in the next section. Therefore, inframarginal rent is a more modern, comprehensive and useful rent concept compared to the classic Ricardian rent concept.

4.5.2. Inframarginal rent

Inframarginal rent is an often-ignored type of rent. Possibly due to the incorrect perception that inframarginal rents are the same as quasi-rents and should disappear in the long run. Another reason may be an assumption of homogenous production costs and efficiencies.

The consequence is that in the fisheries economics literature, average economic performance are often taken as measures of total economic rent. This approach will be misleading in the case of heterogenous producers (Copes, 1972; Panzar and Willig, 1978; Johnon and Libecap, 1982; Karpoff, 1987; Coglan and Pascoe, 1999; Arnarson, 2006; Leonard and Libecap, 2015; Grainger and Parker, 2013; Grainger and Costello, 2016; Arnarson et al., 2017; Arnarson and Bjørndal, 2020; Gochberg and Menaldo, 2020).

Heterogeneity in a fishery can arise from differences in skill and efficiencies (Johnson and Libecap, 1982; Coglan and Pascoe, 1999). More skilled fishermen can earn above normal economic returns, despite the marginal fisherman only earns the normal profit. The average cost will therefore be lower than the marginal cost price, giving an impression of economic rents accruing to all fishermen. In some fisheries the inframarginal rent can be substantial (Asche et al., 2021), while in others it can be quite small (Arnarson et al., 2018).

Heterogenous production costs in aquaculture could result from differences in the quality of a production site, i.e. better biophysical environment. Salmon growth and survival is highly dependent on the water quality, so differences in costs could reflect differences in site quality, as described by

Ricardo's land rent theory. However, other factors such as farming skills, quality of input, and regional factors could also explain differences in production costs. Recently, Pincinato et al., (2021) find that more than 82% of production losses can be explained. Some factors are under the farmers' control, suggesting that skill matters. Examples are fish-specific factors (e.g. species, genetics, and generation), input factors (e.g. vaccines and smolt quality), and managerial factors (e.g. ownership). Factors related to regulation or biophysical factors also play a part. The former suggests that part of the inframarginal rent arises from regulation, overlapping with regulatory rent. Pincinato at al., (2020) also find that environmental factors such as geographical location also plays a part, alluding to the presence of differences in quality. However, their analysis of geographical effects was on a more aggregated regional level rather than at the site level. Hence, more research is necessary to ascertain if site quality matters for the marginal cost curve.

Cost heterogeneity is indicative of inframarginal rents, and Figure 8 documents and increasing cost heterogeneity in the Norwegian salmon industry after 2013. During 2005 to 2013, 90 percent of the costs varied between +/–5 NOK/kg of the median. However, in the latter 5 years the variation has increased by 2–3 times, suggesting increased cost heterogeneity, possibly due to a structural shift.

Previous studies suggest that salmon aquaculture production costs *levels* are affected by many drivers, including feed prices, productivity and economies of scale, technology choice, capital intensity, regulation, and biological issues such as sea lice infestations, disease outbreaks and escapees (Asche et al., 2013; Asche et al., 2020; Iversen et al., 2019, 2020; Pincinato et al., 2020; 2021; Rocha-Aponte and Tveterås, 2019).

The causes behind the increased cost *dispersion* are not well researched. Recent research suggests that a paradigm shift in sea lice treatments from predominantly chemical to non-chemical and mechanical delousing methods have resulted in increased mortalities of large fish (Coates et al, 2021). Costs of delousing have increased by 4-fold over the last decade, the largest increase occurring during 2014–2016 (Nofima, 2021), at the same time as the paradigm shift in sea lice treatments. Sea lice treatments have been shown to have become a major cost component (Abolofia et al., 2017; Asche et al,. 2021a).

Moreover, since the 2000s, stricter environmental regulations have been implemented. Examples are maximum limits for the number of sea lice on farmed salmon and the traffic light system. This type of environmental regulation can lead to the internalization of externalities, and the cost effect would be larger for the firms with higher environmental footprint than for firms with smaller environmental impact. The result would be an increase in cost heterogeneity.

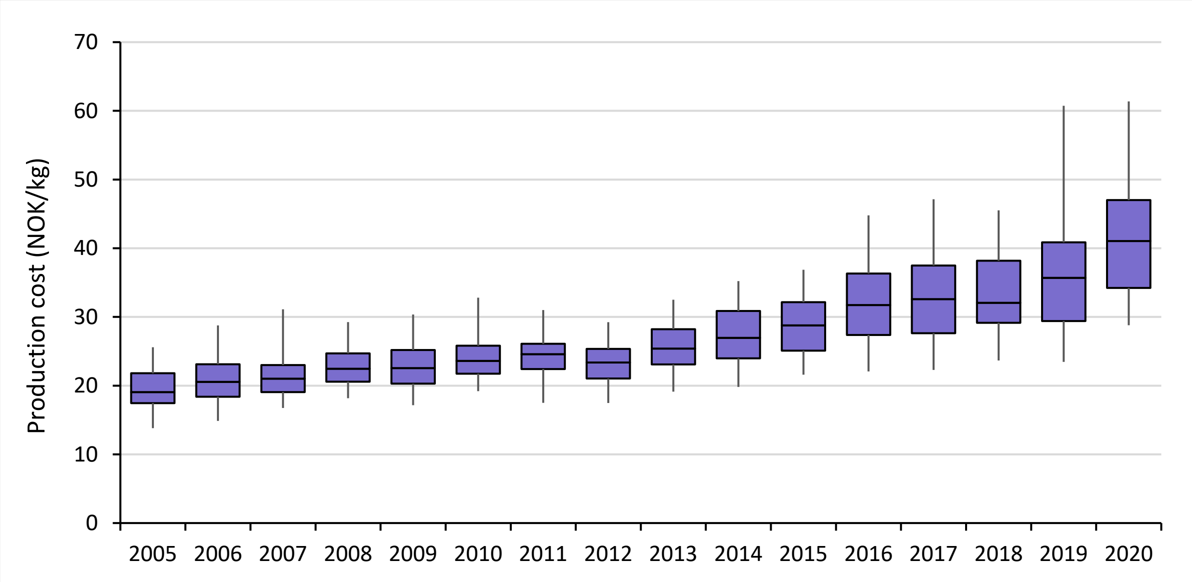

Figure 8. Cost heterogeneity in the Norwegian salmon industry 2005–2020. Source: Directorate of Fisheries.

Increased cost heterogeneity can affect inframarginal rent. However, the extent will depend on the level of marginal revenues in relation to the marginal costs since inframarginal rent is the rent to the left of the industry marginal cost curve, but below marginal revenue. Increased cost heterogeneity combined with increased marginal revenues can therefore lead to increased inframarginal rents. In the second part of this paper, we will empirically estimate the size of the inframarginal rent.

4.5.3. Other types of rent

Other types of economic rent could also be present, such as quasi, investments, and market power rent.

Analysis of short-term data will invariably result in some quasi-rents. However, heterogenous production costs could be sustained, resulting in a long term inframarginal rent.

There could also be investment rents. The high profitability in the sector, combined with barriers to entry, has attracted investments in new technology, such as land based, offshore and semi-closed and closed sea pens. Possibly also market power rents since supply of new aquaculture areas can increase because of innovations.

4.5.4. Summary

The salmon aquaculture industry, in Norway and other production areas, are subject to environmental regulation leading to a production that is below the equilibrium production, suggesting that the economic rent will contain a substantial component of regulation rent. Moreover, the substantial cost heterogeneity also point to the existence of inframarginal rents. The size of total economic and inframarginal rents is an empirical question, and the purpose of the second part of the paper.

4.6. Empirical analysis of economic rents

In this section we estimate total economic, inframarginal and regulation rents. To this end, we apply Coglan and Pascoe's (1999) approach to estimating inframarginal rents. Using firm level cost data, we estimate the industry marginal cost curve allowing us to estimate inframarginal rents as the area to the left of the supply curve, and below the cost of the marginal cost producer below the marginal revenue (see Figure 6). Total economic rent is calculated using the difference between average revenues (= marginal revenues) less average total costs, multiplied by total quantity. We estimate regulation rent as the difference between total economic rent and inframarginal rent.

Annual observations of costs, revenues, production, MAB are collected across a sample of the population of salmon farmers in Norway between 2000 and 2020. In total, the dataset consists of 2056 firm-year observations. The panel data set is unbalanced. In 2000, there are 191 observations, decreasing to 77 in 2019. Between 1990 and 2010, the industry experienced a substantial restructuring (Asche et al., 2013). Not all salmon farming companies are included in the database, and on average owners of around 67% of the total number of licences report to the Fisheries Directorate each year.

The composition of unit production costs is shown in Figure 9, and descriptive statistics in Table 3. Production costs have increased from 22.96 NOK/kg in 2005 to 41.92 NOK/kg in 2019 in real prices, an increase of 83% (146% in nominal prices). The cost increases have been driven mainly by increases in feed, capital (incl. depreciation) and “other costs”. The latter costs reflect increasing costs from dealing with diseases and sea lice infestations (Iversen et al., 2019). The increases in capital costs and depreciation reflect increasing capital intensity in the industry (Misund and Tveterås, 2020).

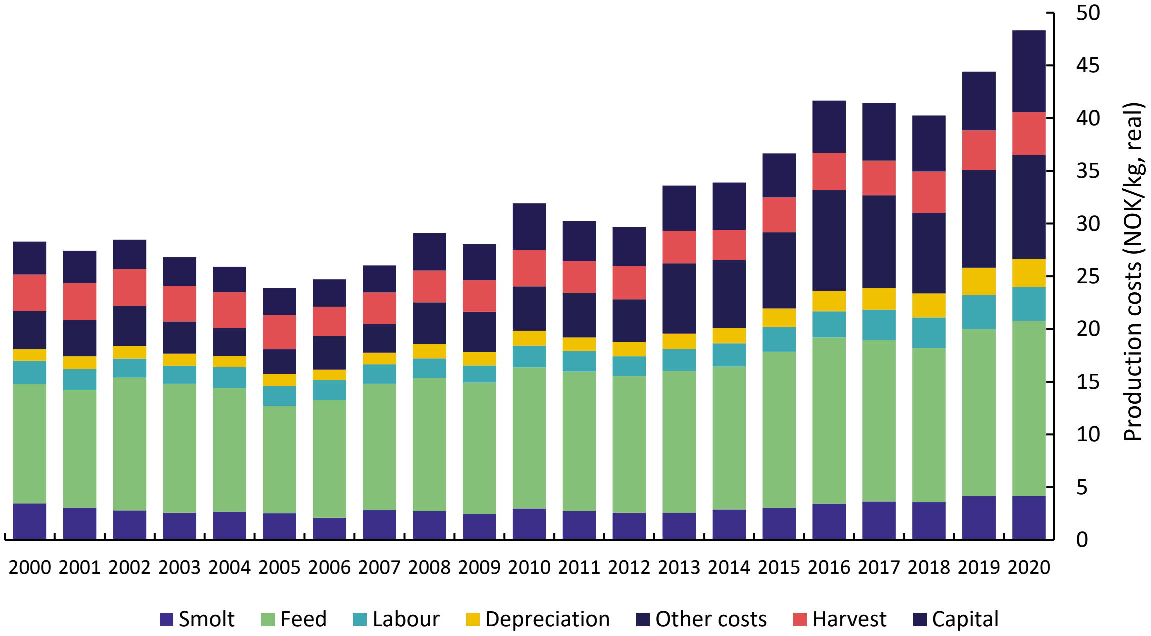

Figure 9. Composition of production costs. Source: The Norwegian Fisheries Directorate and the authors’ own calculations (capital cost).

Table 3. Descriptive statistics.

Year	Mean	SD	P10	P50	P90
Unit production costs	26.59	10.63	16.31	24.56	39.67
Number of licences	6.98	12.44	1	3	17
MAB	13,944	202,448	780	2,340	15,300
Production	8,116	15,447	1,010	3,241	18,005
Feed conversion rate	1.27	0.22	1.0	1.3	1.5
Other costs	5.32	4.78	1.56	3.80	10.71
Capacity utilization	1.36	0.64	0.76	1.32	1.94

The numbers in Table 2 are calculated across all years. The time series variation is described in Figures 10 (unit costs), 11 (Feed conversion rates) , 12 (production efficiency), and 13 (other production costs).

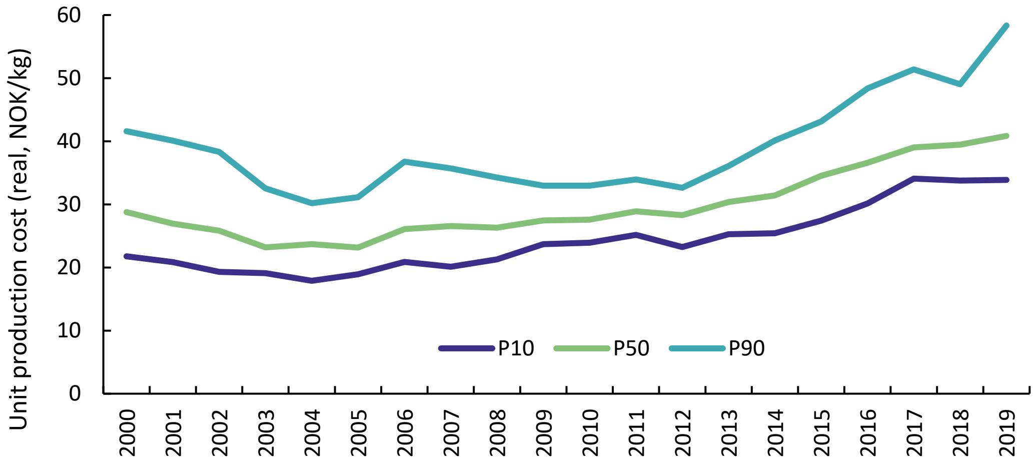

Figure 10. Unit costs for the 10th, 50th and 90th percentiles. Source: Directorate of Fisheries.

Unit production costs have increased since 2005. Since 2012, the variation in costs have increased substantially (as also shown in Figure 8).

The median feed conversion rate (FCR) has increased over the last 20 years, from around 1.2 to 1.3 kilo feed per kilo produced salmon (Figure 10). Biological issues such as diseases and sea lice infestations wil adversely affect FCR since it is calculated as the ratio of feed to produced salmon (i.e. harvested salmon). Biological shocks will impact the ratio, for instance by reducing the production, and therefore the denominator in the FCR ratio. Increased mortalities will therefore result in higher FCR. During 2015–2017 there was a paradigm shift in sea lice treatments methods, resulting in increased mortalities of larger salmon (Coates et al., 2020), an impact which can also be seen in Figure 10.

Figure 10 documents large differences in feed conversion rates between the 10th and 90th unit cost percentiles. The 10th percentile has approximately 50% higher feed conversion rates than the 90th percentile. Since feed represents approximately 40–50% of the production costs, increases in feed conversion rates will have a substantial impact on unit production costs. Differences in feed conversion rates could reflect differences in mortality rates, skill, smolt quality and others.

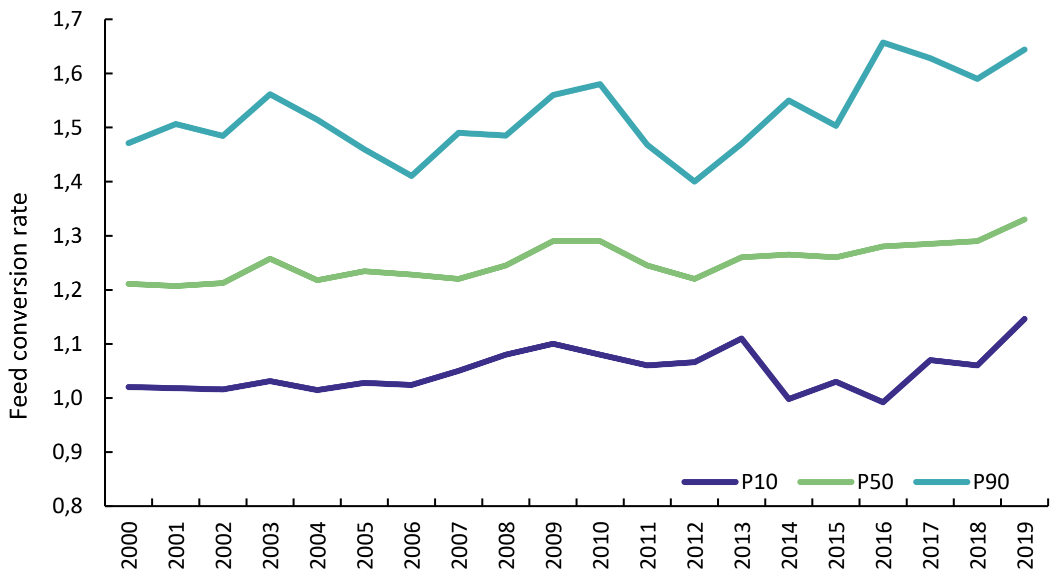

Figure 11. Average feed conversion rate for the 10th, 50th and 90th percentiles of firms.

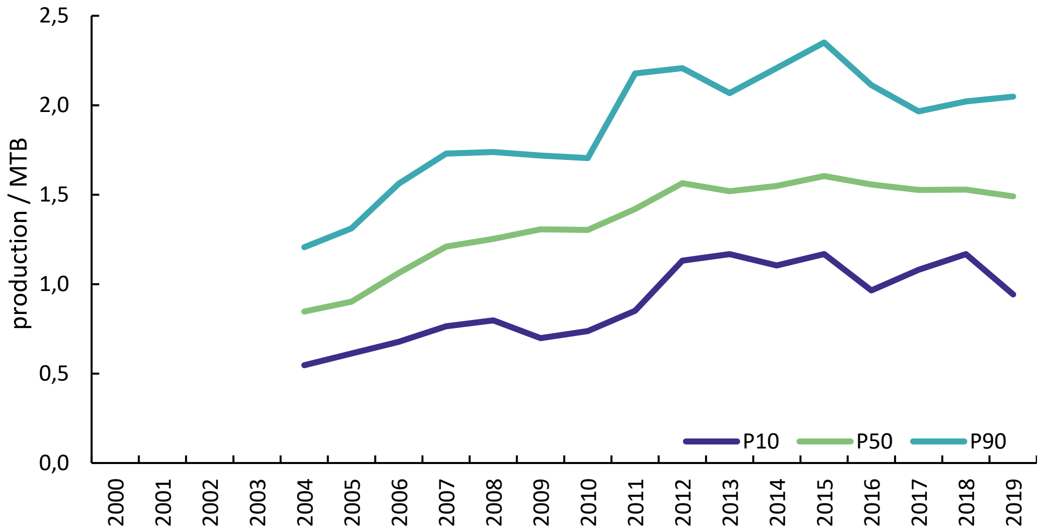

Figure 12. Production efficiency

There are large variations in production efficiency, measured by the ratio of production to MAB capacity (Figure 12). Since MAB is a stock variable while production is a flow variable, it is possible to produce quantities above the biomass restrictions of the MAB capacity limits. Following the MAB regime's implementation in 2005, production soared since MAB capacity limits were originally set at a level substantially above the production levels at the time, and salmon farms responded by closing this gap within 6–7 years, as seen by the increasing curves between 2005 and 2012 in Figure

11. The figure also documents substantial differences in capacity utilization amongst farmers. The 10th percentile firms produce quantities of salmon at around the level of the MAB capacity, while the 90th percentile produce approximately twice as much. Differences in MAB capacity utilization can have an impact on unit costs.

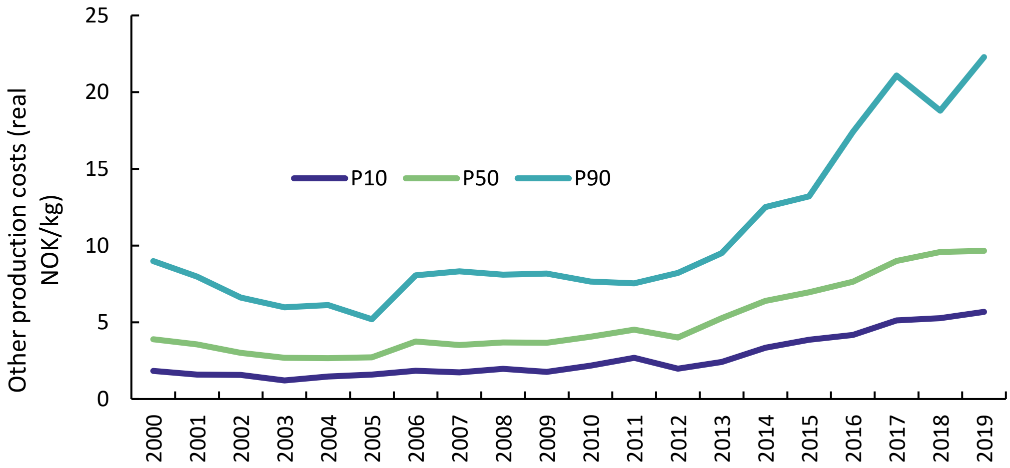

Figure 13. Other production costs

Another measure of production efficiency is the category 'other' production costs (Figure 13). 'Other' production costs contain various residual cost components, including costs related to fish lice treatment and diseases. Figure 13 documents that other costs have increased substantially since 2005 (as was also shown in Figure 9). Moreover, the 90th percentile has shown a formidable intensification, increasing by approximately four times since 2005. In 2019, the level of the other costs in the 90th percentile were approximately twice the median and four times the 10th percentile.

4.6.1. Calculating inframarginal rents: Estimating the industry marginal cost curve

We estimate the industry marginal cost curve using the firm level data on production costs and quantities. The approach follows Cogland and Pascoe (1999). First, firms are sorted according to the unit production costs, from lowest to highest. Then, a stepwise aggregate production cost and quantity curve is created by incrementally aggregating across firms. The industry cost curve is estimated using a polynomial regression of aggregate costs on aggregate quantities (intercept restricted to 0). The industry marginal cost curve is calculated by differentiating the aggregate cost curve with respect to quantity, and the industry average cost curve is calculated by dividing the aggregate costs by the aggregate quantities.

The resulting parameters are reported in Table 4. The *p*-values and R2 are not reported due to the likely existence of multicollinearity between the independent variables. The coefficients in the marginal cost equation are roughly in similar order of magnitudes across the years except for the intercept, which has been on an increasing trend since the mid-2000s, indicating upward shifts in the industry supply curve.

Table 4. Results from the regression model of aggregate industry costs on aggregate production using a cubic regression model (q is aggregate quantity at different levels of aggregation).

	q^3	q^2	Q
2000	7.41×10^{-18}	5.44×10^{-9}	15.21
2001	3.20×10^{-18}	8.26×10^{-9}	14.90
2002	0.21×10^{-18}	3.55×10^{-9}	15.70
2003	0.18×10^{-18}	6.22×10^{-9}	14.99
2004	0.14×10^{-18}	2.24×10^{-9}	15.50
2005	4.16×10^{-18}	3.00×10^{-9}	14.18
2006	2.04×10^{-18}	5.58×10^{-9}	13.97
2007	-1.11×10^{-18}	6.09×10^{-9}	15.31
2008	1.04×10^{-18}	5.90×10^{-9}	17.00

2009	-2.64×10^{-18}	9.86×10^{-9}	16.63
2010	91.6×10^{-18}	-70.9×10^{-9}	26.22
2011	-2.09×10^{-18}	0.10×10^{-09}	18.18
2012	-3.78×10^{-18}	0.11×10^{-09}	18.32
2013	-41.3×10^{-18}	6.25×10^{-09}	22.62
2014	2.73×10^{-18}	4.17×10^{-09}	23.00
2015	-3.88×10^{-18}	014×10^{-09}	22.53
2016	-2.59×10^{-18}	0.14×10^{-09}	27.29
2017	-1.80×10^{-18}	0.11×10^{-09}	29.80
2018	4.98×10^{-18}	-1.07×10^{-9}	32.41
2019	6.23×10^{-18}	3.58×10^{-9}	34.19
2020	-6.52×10^{-18}	0.20×10^{-9}	34.73

Note. R2 and p-values are not reported as they will be unreliable (risk of multicollinearity among the independent variables).

4.6.2. Calculating total economic, inframarginal and regulation rents

The marginal revenue is set equal to the reported average revenue at the farm level. Total economic rent is calculated as difference between marginal revenue less the average cost for the industry, multiplied by the aggregate production. If marginal revenue is higher than the marginal cost found at the total production level, inframarginal rent is calculated as the difference between this marginal costs and marginal costs at each production levels, multiplied by production quantities. If the marginal cost at the total production level is higher than the marginal revenue, inframarginal rent is only calculated for marginal costs below marginal revenue. Regulation rent is calculated as the difference between total economic rent and inframarginal rents.

4.7. Results

In this section we present the results of the analysis of total economic, inframarginal and regulation rents in salmon aquaculture 2000–2020.

Figure 14 summarises the results across the years 2000 to 2020. In all years, most of the economic profit are inframarginal rents.

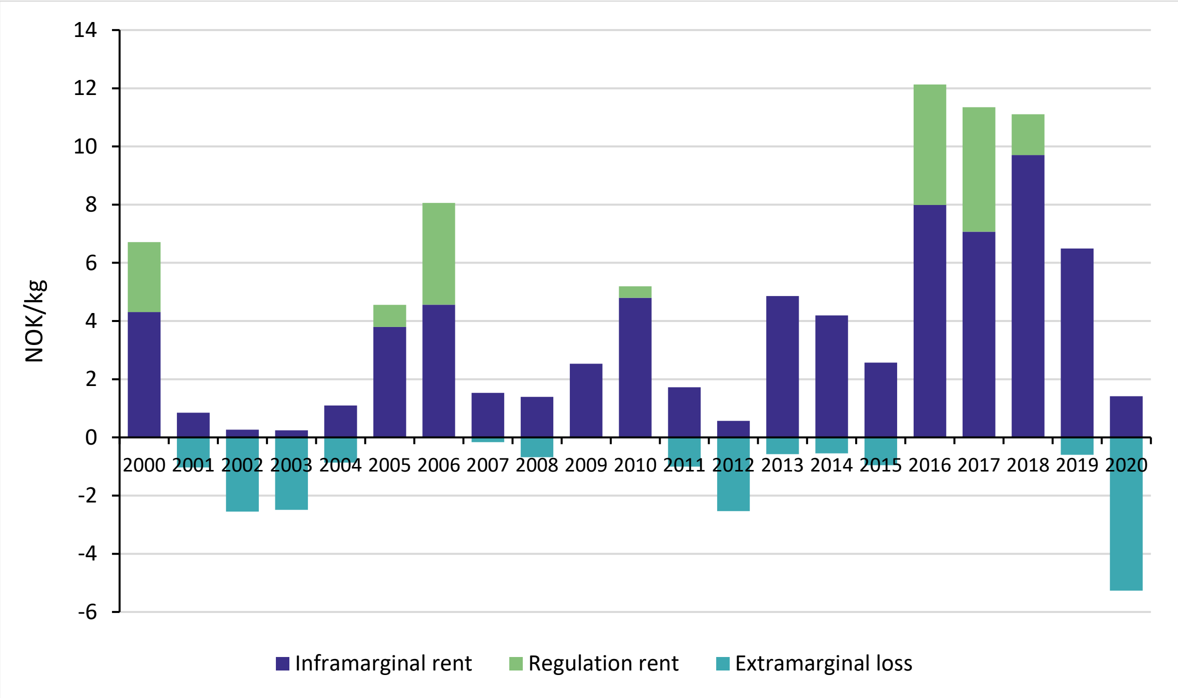

Figure 14. Economic profit, inframarginal rent, and extramarginal total losses for Norwegian salmon farmers 2000–2020.

Between 2000 and 2015, economic rents demonstrated a cyclical pattern, alternating between periods of positive and negative rents. Unsurprisingly, the amount of regulation rent is the highest during the peak periods in the profitability cycles, such as years 2000, 2006, and 2016–2017.

However, since 2015 rents have increased substantially. Between 2016 and 2018, total economic rent was in the order of 11–12 NOK/kg, representing approximately 22–24 percent of revenues. On average total rents were more than 2–3 times higher 2010–2020 than during 2000–2009, and since 2015 nearly 4 times compared to the 2000s. Hence, our results confirm the presence, and increase, in the level of economic rents in the Norwegian salmon aquaculture industry.

We follow Coglan and Pasco (1999) and allocate total rents to inframarginal and regulation rent. Figure 14 documents that inframarginal rents have dominated total economic rent in all years. While substantial regulation rents were present during 2016–2017, they have since dissipated and been replaced by inframarginal rents. Salmon prices have fallen by approximately 5 NOK/kg from 2016 to 2020, but this decrease is insufficient to explain the magnitude in the reduction in total rents. Hence, our results suggest a substantial rent dissipation has occurred since 2016.

The reasons behind this development are not well understood but could be a result of several factors. First, over the last decade environmental regulation has become stricter as documented in Table 2. The regulation has primarily targeted sea lice infestations (e.g. sea lice count legislation and the traffic light system). Moreover, sea lice treatments have become more costly (Abolofia et al., 2017; Nofima, 2021; Asche et al., 2021a). A recent study finds costs associated with sea lice infestations can represent as much as 14 percent of revenues, and that the use of mechanical treatments methods has exacerbated the cost impact (Asche et al., 2021a). Mechanical methods were introduced when the efficiency of chemical sea lice treatments fell around 2015–2016, leading to a rapid transition to new mechanical methods that have resulted in increased mortalities of salmon larger than 2 kilos (Coates et al., 2021). A few years earlier, sea lice regulation was made stricter, but it is not yet known whether there was a causal relationship between stricter sea lice count regulation and the reduced efficiency of chemical treatment methods. Most delousing methods are not 100 percent effective and the lice that are least vulnerable to the treatment strategy will survive and these inefficient sea lice treatment or prevention strategies will exert a treatment resistance pressure, and salmon farming will therefore drive the ecology and evolution of salmon lice (Dempster et al., 2021). Therefore, stricter sea lice regulation can have led to an acceleration of the reduction in conventional chemical delousing methods, facilitating a transition to more costly mechanical sea lice treatments. The cost impact will be larger for firms or production sites which are more prone to sea lice infestation, than other firms/sites, thus increasing the cost heterogeneity.

4.8. Conclusion

In recent years, the Norwegian aquaculture industry has generated high extraordinary profits, suggesting the existence of substantial economic rents. However, very little is known about the nature of the economic rents, and how they are generated. The literature on economic rents in fisheries suggest that rents come in mainly three types, resource, inframarginal and quasi rents. Total economic rent typically entails calculating rent based on industry average costs and revenues, and this approach will not allow for estimation of other types of rents, such as inframarginal rent. Simply relying on average revenues and costs to calculate resource rents is not sufficient for describing and explaining rent creation and dissipation in salmon aquaculture. Previous literature in the fisheries economics literature suggests that the other two types of rents could also be important elements of total economic rent.

Moreover, it is also important to carefully analyse the determinants of the resource rent since their origins will have an impact on the type of optimal policies for rent capture should be implemented. Some rents are true scarcity rents and should be taxed using rent taxation, while other rents arise due to imperfect environmental regulation. The latter type of rents represents market failure and inefficiencies, and have not been sufficiently corrected by direct regulations. Economic mechanisms such as subsidies or distortionary taxes, such as Pigouvian taxes would be more appropriate. Other rents are wanted, such as political rents. Restructuring and capacity reduction in the Norwegian fisheries during the 1990s and 2000s was carried out to improve profitability in the fishing fleet. Other types of rents, such as inframarginal rents, could arise from heterogenous skills and could promote innovation.

The purpose of this paper is twofold. First, we contribute to the literature by providing the first ever analysis and description of economic rent generation and dissipation in salmon aquaculture. We provide a description of which type of rents could be generated in salmon aquaculture. This knowledge will be important for the social planner deciding on optimal policies for rent capture. Second, we examine the existence of both regulation and inframarginal rents.

Our analysis suggests the existence of both inframarginal and regulation rents, and that the former has dominated total economic rent in most years. We find that total economic rent have increase by nearly 4 times since the 2000s. While 2016 saw a substantial increase in economic rents, both regulation and inframarginal, regulation rent has in recent years dissipated in favour of inframarginal rent, and we explain this by internalization of externalities due to stricter environmental regulation as well as increased sea lice mitigation costs arising from a paradigm shift in sea lice treatment methods.

Our results provide important insight into the persistence of economic rents in Norwegian salmon aquaculture. The increase in inframarginal rents in recent years as well as dissipation of regulation rent should be of concern, especially as increased costs from sea lice infestations is a likely candidate behind the development.

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4.10. References

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