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Licenses, governance, concentration and market imperfections in the Norwegian salmon industry

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ABSTRACT

A proposal of a 40% rent tax on salmon farming in Norway in September 2022 prompted debate about the level of market imperfection in the Norwegian salmon industry and the magnitude of the available rent at the primary stages of production. The production of farmed salmon in the coastal areas of Norway is contingent on having licenses for aquaculture practices. This industry has evolved into a huge sector with large corporates holding numerous licenses and successfully exporting salmon to many countries across the world. This development has increased concerns about concentration and possibly the creation of rents and market imperfections in the industry. In this study, the markup approach and stochastic frontier methodology were used to investigate market imperfections in the Norwegian salmon industry. The analysis is based on salmon producers' and primary processors' financial data for the 2008–2018 period. In order to interpret the markup estimations, we analyzed available data on the development of licenses and operational costs, and we explored the literature on the industry's governance. The findings indicate a low level of concentration and a low level of market imperfections, which was also reduced over the study period, and was higher for small and medium-sized firms.

KEYWORDS

Norway; salmon; licenses; governance; rent; concentration; markup; market power

Introduction

Concentration in the agricultural input and food processing sectors is of growing concern among different food supply chain stakeholders (Clapp, 2021, 2023). Concentration in food supply chains and the possible creation of market power are not just limited to developed countries (Sexton & Xia, 2018),

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but are also recognized in low- and middle-income countries (Barrett et al., 2022). Market power and concentration are two different concepts and concentration, which refers to market share, does not necessarily signify the existence of market power (Kaplow, 2015). Although concentration can enable firms to take advantage of their position in the market to depress prices to input suppliers or elevate prices of final products, it could also be due to scale economies. With economies of scale, larger firms can achieve lower unit production costs and thus offer lower product prices (Paul, 2001). Concentration in food supply chains is mainly fueled by increasing consolidation and vertical coordination and by the worldwide food price inflation and volatility of 2007–2008 (McCorrison, 2014). Although increased concentration does not necessarily lead to the exercise of market power (Crespi & MacDonald, 2022; Deconinck, 2021; Kaplow, 2015), the concern is that unfair trading practices (UTPs), due to higher concentration and consolidation among market intermediaries, will harm farmers and small businesses in the chain. This could cause market inefficiencies, curtail investment and, in the most severe cases, the exit of otherwise viable entrepreneurs (Fałkowski et al., 2017, ch1).

Contrary to agri-food chains, in aquaculture value chains, such as the farmed salmon value chain, concentration is an issue of concern at the production and primary processing stages (Fischer et al., 2017). For a long period of time, Norwegian salmon producers have had good margins for their products (Sikveland et al., 2022), been leading the way regarding the development and implementation of new technologies, and been the most cost-effective producers globally (Afewerki et al., 2023; Aponte & Tveterås, 2019). There are, however, different positions on the source of profitability in the salmon industry. Several scholars such as Oglend et al. (2024), Misund et al. (2025), Oglend and Soini (2020) and Misund and Tveterås (2020) all argue that there is a regulation rent in salmon aquaculture, while Misund and Tveterås (2020) posit the availability of “inframarginal rent” and possibly also “quasi-rents.” In contrast, Greaker and Lindholt (2021, 2022) do not argue against the existence of either regulation rent or inframarginal rent, but they are skeptical of the presence of inframarginal rents. Nevertheless, many scholars take it as a fact that active government regulation has secured a sizeable extra profit in the Norwegian salmon industry, which has been regulated since its small-scale beginnings in the 1970s (Hersoug, 2021). Since then, the industry has witnessed massive transformation and growth, and Norway plays an important role in the international salmon market. The favorable natural conditions for salmon production in Norway and the strong demand from the retail side have induced concerns about market power availability in the salmon supply chain. Following the introduction of the MAB licensing scheme in 2005 and more prominently after 2012, increasingly stringent regulations aimed at mitigating environmental

externalities have resulted in constraints on production growth at the same time as demand for salmon has been growing, resulting in exceptionally high prices and thus profits. This rent was the motivation for the introduction of the “rent tax” in the Norwegian aquaculture sector (Oglend et al., 2024).

The salmon industry in Norway was initially intended as a vehicle to improve the quality of life in coastal communities (Hersoug et al., 2021; Misund et al., 2023). However, this changed as the industry developed with production growth and currently salmon aquaculture in Norway produces roughly half of the total production of the world’s farmed Atlantic salmon (Iversen et al., 2020). For the period 2016–2019, two Norwegian exporting groups of producers and intermediaries supply salmon products on a global scale. The most valuable destinations for both groups are European markets but they also serve the US, Asian and African markets. Overall the producers trade in 109 different markets, while intermediaries serve 120 markets (Straume, Asche, & Oglend, 2024). Nevertheless, on average, there were 40 buyers for each exporter in the study period (Straume, Asche, Oglend, et al., 2024). Furthermore, there is large heterogeneity in the number of buyers within as well as between different destination markets, and the main buyers in the largest markets source their products from both producers and intermediaries (Straume, 2024). The imports by EU countries mainly consist of fresh whole products originating from Norway and entering EU Member States through Sweden and Denmark that act as “trade routes” for further distribution to secondary processing sites, like in Poland for example or retail markets in France. Buyers of Norwegian salmon are typically large European supermarket chains that have a certain level of bargaining power. The vertically integrated salmon producers in Norway (who also own the primary processing) benefit from being able to supply large quantities as required to ensure stable supplies to the consumer market (Kvaløy & Tveterås, 2008; Olafsdottir et al., 2019). Furthermore, the large vertically integrated firms also have better access to distant destinations and more information to target more profitable markets (Oglend et al., 2022; Straume, Asche, & Oglend, 2024).

Asche et al. (2018) have noticed that as a company’s share in total sales increases, its profitability increases. This finding, along with the increased concentration and availability of economic rent in the Norwegian salmon industry, may indicate that market imperfections (market power) can be observed in the Norwegian salmon production and processing industry. Furthermore, concerns of available market power in the salmon supply chain are associated with vertical coordination between large Norwegian companies and secondary processing subsidiaries in different countries. These relations may further influence the power balance in the salmon value chain. However, the focus of policymakers is mainly on available

rents in the salmon industry as confirmed by the rent tax scheme that was approved by the Norwegian Government in May 2023. The Government's initial proposal for changing the tax structure on 28th September 2022 (Norwegian Government, 2022) raised concerns within the salmon industry (Misund et al., 2025). In this initial proposal, a 40% cash-flow based rent tax on salmon, trout and rainbow trout producers' rent during their sea-based operations, on top of corporate tax, was proposed. Activities that take place before and after the sea phase should fall outside the scope of the rent tax (Council of State, 2023). The proposal was based on similar taxation as in natural resource sectors such as oil, natural gas, hydropower and onshore wind power (Amundsen, 2024). Before eventual government approval in May 2023, the tax rate was reduced to 25%,¹ with an increase in the discount on the wealth tax value for farming concessions from 50% to 75%.² Additionally, a basic tax-free allowance was set at 70 million Norwegian krone (NOK) for each company (Ministry of Finance, 2023). In their study, Misund et al. (2025) have shown that the stocks return of the firms in the target industries are negatively affected in this period.

This rent taxation scheme has motivated our research on concentration, the size of markup, and potential market imperfection (market power) in the Norwegian salmon industry, using the markup approach. Peters (2020) has formulated market power as an important determinant of static allocative efficiency. He also mentions that the welfare consequences of particular policies depend on how firms' markups change in response. Markup here refers to the difference between the cost to produce a commodity and the retail price that's charged for that commodity (Axarloglou, 2015). The market power is a source of one type of economic rent that can be measured by markup index (Schwerhoff et al., 2020). Market power measuring approaches such as the Lerner's index (1934) are standard measures of markup size.

Analyzing the structure of the salmon industry in Norway is the first step for exploring how concentration has developed in this supply chain. Furthermore, we review earlier research on the governance of the salmon supply chain and especially the role of licenses, production costs, and international market prices, which may also influence possible market imperfection in the production stages of the salmon supply chain. By applying a concentration rate approach and then employing markup analysis on salmon producers who are typically also primary processors, we can evaluate whether potential concentration in the chain is available and if it has resulted in market imbalances. We have applied the novel approach of Kumbhakar et al. (2015) for the analysis of market imperfection, which is based on an input distance function approach using firm-level data from primary salmon producers and primary processors for the 2008–2018

period. The results show that despite having a relatively low concentration rate in the Norwegian salmon farming industry, we observe mild market imperfections. We argue that it is rather the governance structure of the salmon supply chain, and in particular the licensing scheme, production costs, different efficiency levels, international market prices, and availability of possible regulatory rent that cause the slight market imperfection in the primary stages of salmon harvest and production.

This paper is structured as follows: in section “The salmon industry in Norway” we discuss the structure of the salmon industry in Norway, specifically the environmental challenges, regulations, licensing schemes, concentration, and market development. Section “Market imperfections in seafood supply chains” reviews earlier studies on market imperfection in seafood supply chains to highlight similarities and differences, followed by providing the conceptual framework, empirical model, estimation strategy and data description in section “Methodology and data”. Finally, the estimation results, discussion and conclusion are provided.

The salmon industry in Norway

With 8.8% of value share in 2022, Norway stood as the second largest exporter of aquatic animals after China from which salmon is the major export product (FAO, 2024). Salmon can be farmed in certain coastal areas of the world where seawater temperature and other natural conditions are favorable for the biological/morphological characteristics of the species (Asche & Bjørndal, 2011). Farmed salmon is produced in Norway, Chile, Scotland, the Faroe Islands, Ireland, Iceland, Canada, the USA, Tasmania and New Zealand. In 2021, from a total global production of more than 2.65 million tons of farmed salmonids (MOWI, 2022), 1.53 million tons were produced in Norway (KONTALI, 2022), while Chile came second with more than 0.692 million tons produced (FAO, 2023).

The Norwegian salmon farming industry is highly successful in terms of rapid increases in production volumes and exports to international markets (see Figure 1).³ The success has been motivated by innovation and the development of farming technologies, juvenile production, fish health, breeding and genetics, feed, primary fish processing and regulations since 1970 (Afewerki et al., 2023). However, the industry similar to other aquaculture practices still faces several challenges, mainly environmental challenges including diseases, escapes, and water pollution. Furthermore, the expansion of salmon aquaculture production has an external negative effect on the survival of wild salmon stocks (Asche, Eggert, et al., 2022; Nikitina, 2019). It is primarily related to the interaction between fish farming and its surroundings that can originate disease spillover by salmon lice and genetic

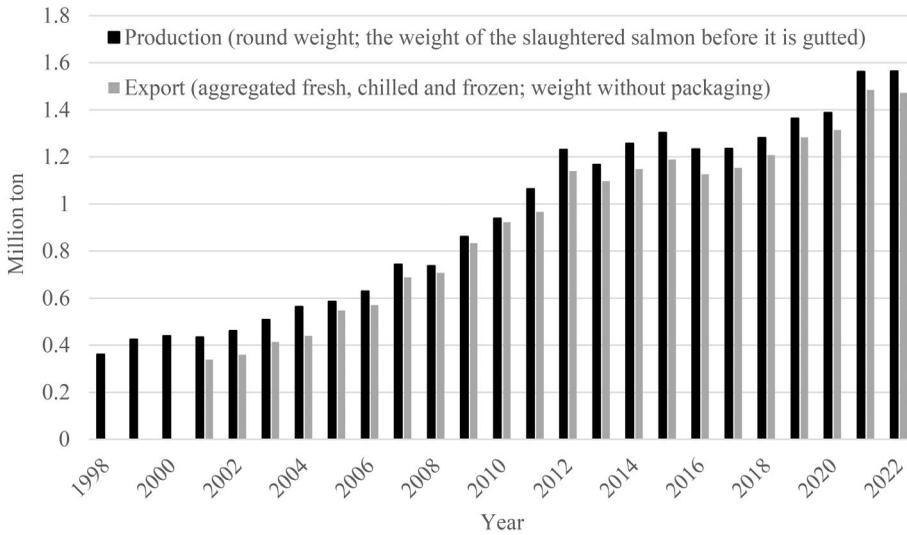


Figure 1. Norway's salmon production and exports in whole fish equivalent (WFE).

Source: Directorate of Fisheries (Fiskeridirktoratet) sale statistics (Norwegian Directorate of Fisheries, 2025b) and annual report (Norwegian Directorate of Fisheries, 2025a).

pollution through escapees (Asche, Eggert, et al., 2022). Although the profitability of the industry is high, it is very cyclical (Asche et al., 2017), as is common in commodity industries. Additionally, regulatory constraints due to environmental challenges impose a limit on production growth. As a result, in a period of rising demand, supply constraints have resulted in high prices (Misund, 2022).

From the mid-1980s until the mid-2000s the industry was characterized by high productivity growth (approximately 20% annual increases in production from 1985 to 2005), resulting in substantial cost reductions (Misund, 2022), with production costs in 2016 being one-third of the production costs in 1985 (Iversen et al., 2020). However, since 2006, the situation has reversed and the rise of production costs has averaged 7% annually and thus, steadily higher salmon prices are necessary for covering a normal return (Aponte & Tveterås, 2019; Iversen et al., 2020; Misund, 2022).

Misund (2022) studied cost development in the Norwegian aquaculture industry and identified the five most important cost drivers since 2005. First, higher prices for factor inputs, especially for feed (approximately a 50% increase from 2005 to 2020) have made a significant contribution to cost increases during the period but a large part of that cost increase is due to a depreciation of the NOK. Second, investment growth, driven by productivity improvements, has resulted in increased capital costs (Figure 2 shows the investment development in the Norwegian salmon industry). Third, stricter regulations have led to increased costs, including the cost of delousing treatments. Fourth, high global market prices resulting from stricter environmental regulations around the world have allowed farmers

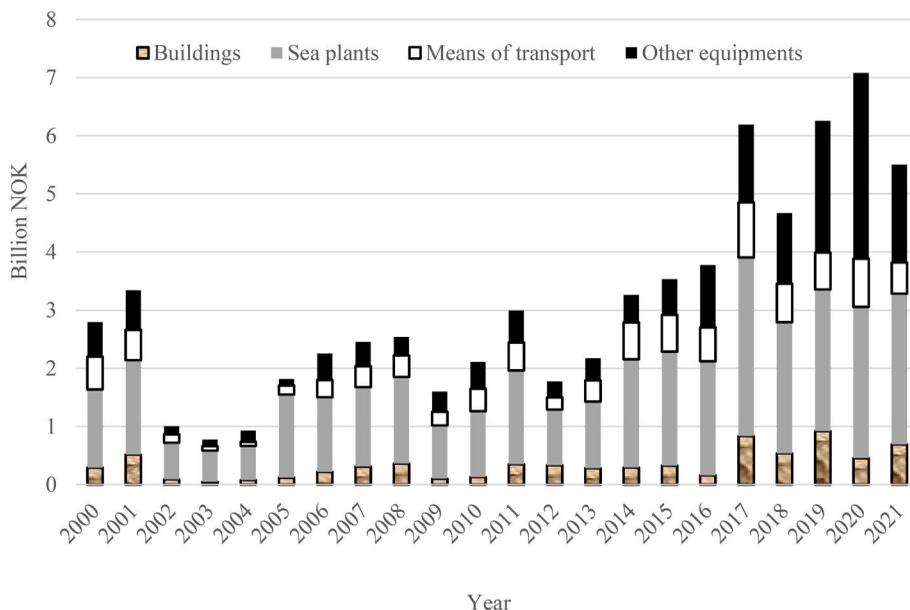


Figure 2. Equipment purchases by the type (values in billion NOK).

Source: Directorate of Fisheries (values are adjusted for inflation using the producer price index (PPI) available by SSB,⁴ for the base year of 2022).

to develop expensive capacity utilization strategies (e.g., post-smolt) to grow their businesses despite restrictions on supply growth. Finally, the costs of biological risks or costs related to deviations from optimal growth conditions (e.g., disease, stress, reduced growth, and mortality) have risen significantly since 2005 when environmental regulations were tightened. This final cost factor has not been reported on directly but was estimated by Misund (2022) by comparing the actual feed conversion rate to an ideal feed conversion rate, thus providing a measure of inefficiencies in production due to biological risk factors. The actual feed conversion rate decreases with the growth rate, mortality, escapees, other production losses and feed waste. Therefore, a considerable share of increased feed costs, the most important cost factor for salmon farmers, is due to biological risks. After 2005, these cost increases, have been marked by a tightening of regulations, especially environmental regulations and although the reasons behind the cost increases are complex, these regulations and the producers' responses to them seem to be large contributors (Misund, 2022). By comparing salmon production at the international level, Iversen et al. (2020) found approximately similar reasons for the rise of the costs of salmon production. Notably, in a profitable industry with production constraints, producers will maximize profits by increasing production and engaging in expensive mitigation activities (e.g., delousing), even though that moves costs upward along the right-hand side of the average cost curve.

Environmental challenges and regulations

Since its start in the 1970s, the growth of the Norwegian salmon aquaculture industry has been supported by the regulatory framework of the Norwegian government. Like in other salmon producing countries, production in Norway is regulated by limiting the number of sites with licenses and additional limitations associated with each license (Hersoug et al., 2021). The licensing schemes are a regulatory approach to deal with endogenous externalities by limiting the environmental footprints resulting from salmon production (Jensen et al., 2024). Hersoug (2021) gives a good overview of the development of regulations in the Norwegian salmon aquaculture industry, which are summarized in Figure 3. The objectives of the Norwegian licensing scheme have changed over time, from rural development and the building of a small-scale industry in the early days to increasing focus on limiting environmental externalities since the 2000s, to the extent that from 2012 production growth has been very constrained. Different regulatory schemes were used early on, including the 1973s “one man, one license” regime, which was abolished in 1991, that had a key aim of supporting rural development. Furthermore, in the first decades, net pen volume and density restrictions were unsuccessfully used to control production volume, which in combination with immense productivity improvements resulted in overproduction, and trade conflict with competitors on both sides of the Atlantic. Finally feed quotas, implemented in 1996, were successful in controlling growth but turned out to have a negative impact on quality and fish health and were in the end considered unethical from an animal welfare perspective.

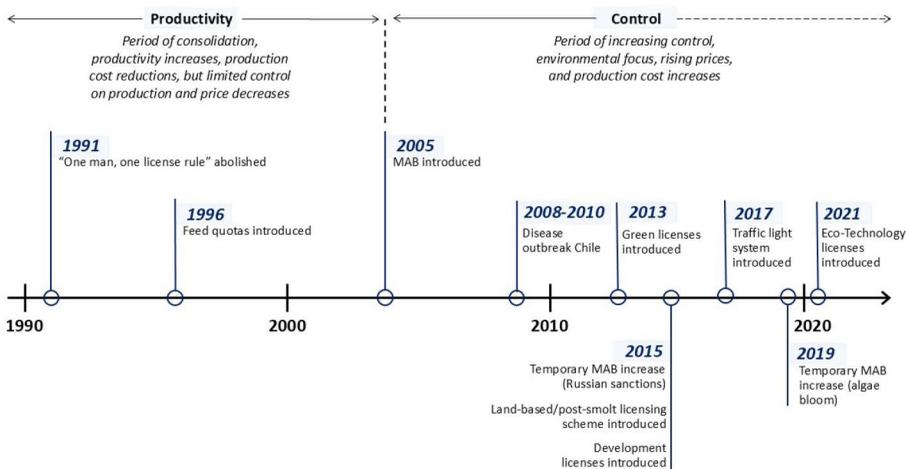


Figure 3. Timeline of license development and other key events in the history of the Norwegian salmon industry.

Source: Hersoug (2021), Hersoug et al. (2021), Osmundsen et al., (2022) and the authors' own interpretation.

Maximum allowable biomass (MAB), the current cornerstone of the Norwegian salmon aquaculture regulatory system, was introduced in 2005, thus regulating both total production and the carrying capacity of each site, using the same criterion (tons). The MAB operates in such a way that at any point in time biomass cannot exceed a given threshold that is normally 780 tons (Oglend et al., 2024). This marked the start of a period of increased environmental focus, control and eventually, once the salmon farmers had reached their MAB limit a few years later, resulted in supply constraints, high prices and production cost increases. Since 2005, MAB has been at the center of the Norwegian regulatory system, although it has been refined and strengthened over the years to effectively regulate the industry by supporting innovation and allowing sustainable growth (Hersoug, 2021). Further new environmental regulations through licenses were introduced to enable farmers to increase their production if they developed and adopted farming methods that could potentially diminish the environmental impact of salmon farming. They consist of “green licenses,” introduced in 2013 to reduce the impact of sea lice and escapes, “development licenses,” introduced in 2015 to improve environmental sustainability, and “eco-technology licenses,” introduced in 2021, to solve environmental and areal challenges (Osmundsen et al., 2022). Although not a part of the ordinary licensing scheme, the capacity increase from these special licenses (e.g., development licenses) can be substantial. Additionally, the land-based and post-smolt licensing schemes were introduced in 2015 to promote the development of potentially more sustainable farming methods due to shorter times at sea (Hersoug, 2021). In addition to new licensing schemes, temporary MAB increases have been allowed in response to production shocks, such as the one related to sanctions on Russia in 2015 and algae blooms in the north in 2019.

The increased control of production is characterized by stringent national regulations that aim to control environmental concerns, fish health, and biology (Hersoug, 2021). However, sea lice concentrations and the effects of sea lice on wild salmon stocks are still a challenge and from policy perspective considered the most critical environmental problem related to salmon production (Jensen et al., 2024) and have become central sustainability measures and thus limiting factors to growth (Hersoug, 2021; Nikitina, 2019). In 2017, a traffic light system for growth was introduced. The system is aimed at preventing lice outbreaks by allowing farmers to increase their MAB if the lice status is green and forcing everyone in the area to reduce their production if it is red (Hersoug, 2021). The environmental externalities of salmon production and the resulting licensing schemes imposed through regulation, have limited the growth in the industry (Osmundsen et al., 2022). Research suggests that these growth

constraints have contributed to the formation of (regulatory) rent in the industry (Misund et al., 2025; Misund & Tveterås, 2020; Oglend et al., 2024; Oglend & Soini, 2020).

An important issue of concern for the salmon industry is disease outbreaks. Such biological shocks have been known to impact market price developments (Asche et al., 2017). Diseases are the main cause of production losses both directly and indirectly due to mitigative actions taken to reduce direct losses. In addition to animal welfare issues, production losses have significant economic consequences. Despite more stringent regulations, remaining in a range of 10–16% over the last 20 years, the loss rate in Norwegian salmon farming has remained relatively stable, indicating little improvement. Therefore, by taking the rapid production increases over the period into account, total production loss has risen at a similar rate. Although the direct impact of diseases in Norway has not been significant since the introduction of oil-based vaccines in 1992, they continue to impact productivity, production costs and profitability indirectly due to regulations aimed at limiting the transmission of diseases to wild salmon stocks (Pincinato, Asche, Bleie, et al., 2021). It must be added that the disease outbreak of Chile's salmon production in 2010 increased the international prices of salmon and benefited Norwegian salmon farmers (Iversen et al., 2020). Furthermore, in 2016, a harmful algae blooms (HABs) outbreak in Chile reduced the production of salmon by about 20% and affected the industry heavily (Ceballos-Concha et al., 2025). This inverse effect should be considered in the analysis of salmon markets.

A future transformation of the conventional open net pen production system toward a more sustainable one is increasingly plausible as technology is being developed for closed/semi-closed systems, land-based operations and offshore farms to mitigate the environmental risks of open cage systems. However, these new production technologies have their own challenges (Misund et al., 2024), and there is resistance to change on behalf of incumbent players (Gudbrandsdottir et al., 2021). Moreover, research indicates that ongoing industry challenges (e.g., mortality, biological costs, diseases), despite major technological advances and economic success, are, at least in part, related to a combination of the licensing scheme and the profit-driven endogenous feedback structure of the system (Gudbrandsdottir et al., 2025). Specifically, growth constraints in times of high demand create regulatory rents that, in the absence of other avenues of growth, incentivize the intensification of production (Oglend et al., 2024; Oglend & Soini, 2020).

Concentration

Concentration in the Norwegian salmon farming industry has been the topic of discussion for many years (Asche et al., 2013; Hersoug et al.,

2021), and the concentration rate in license holding and salmon harvesting is an important trend that motivated this study on possible market imperfection in this supply chain. The majority of farmed salmon in Norway is produced by large companies. The salmon industry in Norway has moved from a large group of smallholder producers within a “one man, one license” regime to fewer large salmon production and processing firms. Figure 4 shows the relation between the number of licenses and firms during 2000–2021.

Table 1 shows the structure and development of license ownership in Norway, displaying two different trends. The number of licenses that were issued from 1994 to 2020 has increased and they’ve mainly gone to larger enterprises over this period. Large enterprises refer to enterprises with more than six official licenses for harvesting salmonids (KONTALI, 2019). Additionally, this table shows a sort of eradication of small producers and a strengthening of larger enterprises.

Table 2 shows the importance of large and small enterprises in the Norwegian salmon industry by considering the MAB restriction ceiling of the firms in the last year of our analysis (2018), which is not very different than the year 2020.

This development of license distribution is a sign of increase in the concentration rate (CR), which can be measured by considering the level of harvest among the top 20 major salmon producers.⁵ Figure 5 shows the development of the CR for the top 1, 4, 10 and 20 firms (CR1, CR4, CR10 and CR20) for the 2009–2020 period. As can be seen, the CR was stable

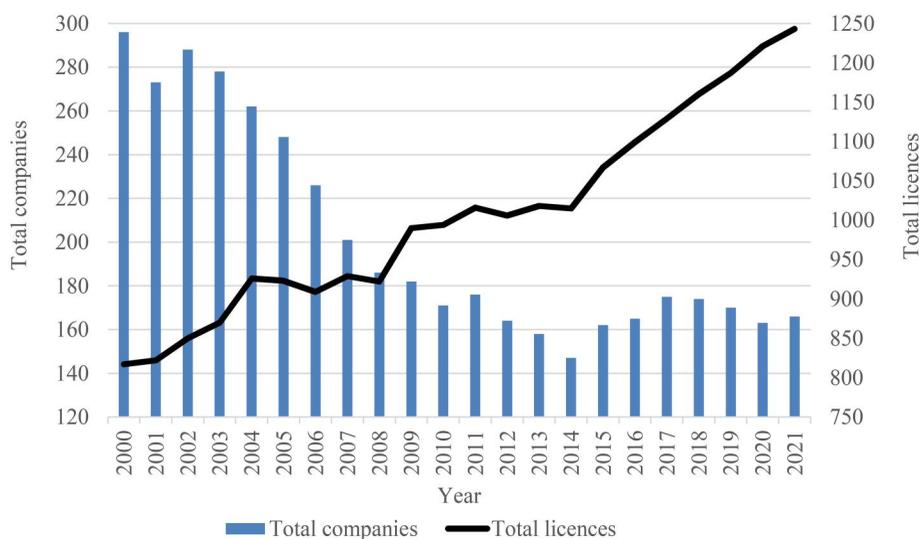


Figure 4. Number of companies and licenses for the production of Atlantic salmon, rainbow trout and trout.

Source: Directorate of Fisheries.

Table 1. The structure of license distribution between enterprises and its development from 1994 to 2020.

		1994	1998	2002	2006	2014	2016	2018	2020
No of Enterprises with different licenses	1 license	221	65	45	34	14	13	13	9
	2–5 licenses	130	95	95	80	52	47	48	47
	6–10 licenses	9	15	12	9	15	18	20	20
	> 10 licenses	5	15	18	19	20	21	21	19
Total number of licenses		692	760	846	889	1057	1123	1165	1231

Source: KONTALI (2021).

Table 2. The breakdown of the salmon industry based on the size of the licenses and the MAB distribution in 2018.

Company	NO of licenses	MAB	MAB distribution
Large companies (6 or more licenses)	982	807180	84%
Small & mid-sized companies (1–5 licenses)	165	131173	14%
Other, not commercial	18	16908	2%
Total	1165	955261	100%

Source: KONTALI (2019).

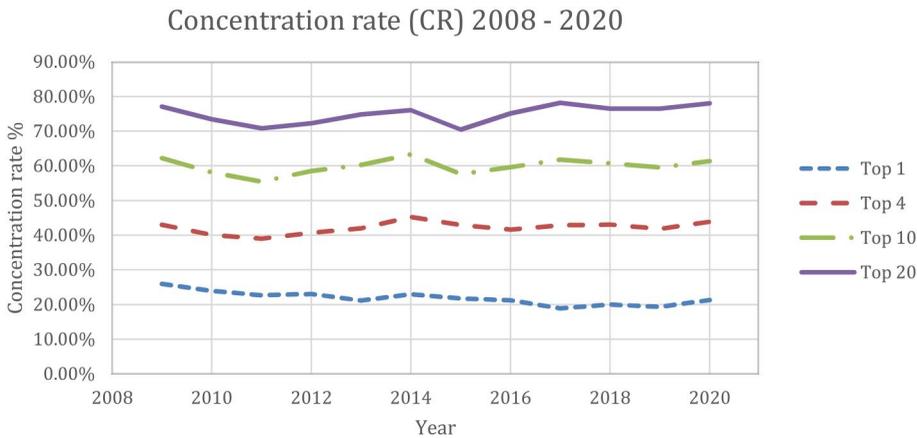


Figure 5. Concentration rate of the top 1, 4, 10 and 20 salmon producing companies.

Source: Data extracted from different KONTAL annual reports.

but relatively high for this period and during this period the annual supply of salmon increased for Norway (see Figure 1).

Available data shows that “Mowi Norway AS,” “Salmar ASA,” “Lerøy Midt AS” and “Cermaq Norway AS” were the top four salmon producers in Norway in 2018 (before the outbreak of the COVID-19 pandemic and the last year of our study) and the CR of the top 1, 4, 10 and 20 firms (CR1, CR4, CR10 and CR20) in 2018 was 20%, 43%, 61% and 76.5% respectively, which was approximately stable during 2009–2020. As we can see, both the license holders and the salmon harvest are relatively concentrated compared to many agricultural products. Nevertheless, the concentration rate of CR4 that we have estimated in this study for 2006–2020 (39%–45.2%) is less than the critical level. The CR4 under 55% is usually a

sign of an unconcentrated market (Kvålseth, 2018). In another study, Pandey et al. (2023) have estimated both CR4 and Herfindahl-Hirschman Index (HHI) for Norway considering the period 2011–2020. They found CR4 around 50% and HHI of approximately 0.1 for their study period. The HHI less than 0.15 is also a sign of unconcentrated market (Kvålseth, 2018). Despite having low levels of HHI and CR4 on the production side of the salmon industry that do not reflect the concerning level of concentration yet, the possibility of market imperfection cannot be revoked as economic rent may be present in this industry. Furthermore, considering the export markets, the concentration of export share is observed in the Norwegian salmon industry at the firm level. In their recent study, Straume, Asche, and Oglend, (2024) have shown that for the period 2016 to 2019 and for the top four salmon export products namely fresh whole, fresh fillets, frozen whole and frozen fillets, HHI higher than 0.15 is observed for all four products at the exporting producer level and for fresh fillets at the exporting intermediaries level.

Salmon market developments

Exports of Norwegian salmon play an important role in the international salmon market. Salmon from Norway is a homogeneous commodity product and is exported mainly as head on gutted whole fresh fish to avoid taxation on value-added products. Cost efficiency in production is the competitive edge for the primary producers of global commodity products like salmon (getting the biggest possible margin per unit produced) (Olafsdottir et al., 2019).

Figure 6 shows the average operational costs of the production of salmon (farm/plant gate), the revenue of selling salmon per kg in the Norwegian market (farm/plant gate) and the export prices of fresh/frozen salmon (Norwegian border) adjusted by using PPI for the 2022 year. The operational costs of fish production and the selling revenue per kilogram per year were acquired from Norway's Directorate of Fisheries. The operational costs include the cost of smolt, feed, insurance, salary, depreciation, slaughter, shipping and other operating costs. On average, salmon production costs rose during the 2008–2021 period. Only a period of slight reduction can be recognized between 2016 and 2018 and after 2020. The depreciation of NOK in the period after 2014 is a crucial factor that affected the level of cost and the revenue of salmon production in Figure 6 (Benedictow & Hammersland, 2022). The export prices are the annual average of weekly prices. As we can see in Figure 6, on average and for most of the period between 2009 and 2021, Norwegian salmon producers had good margins for their products, which is mainly dependent on salmon price levels.

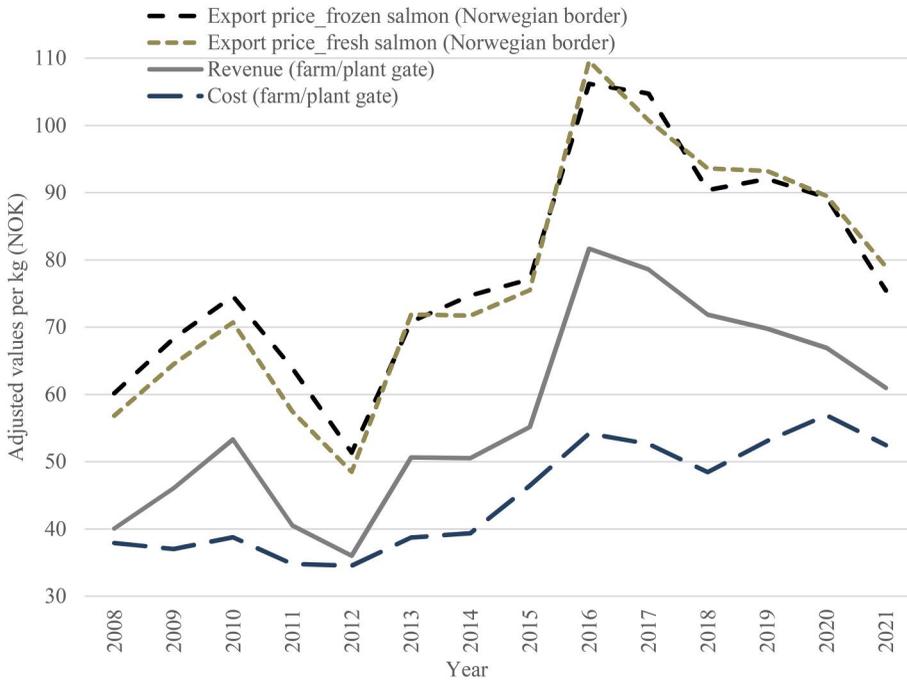


Figure 6. The values of salmon production costs, selling revenue and export values for fresh and frozen (NOK per KG) adjusted with PPI with the reference year of 2022. Source: Norway's Directorate of Fisheries and SSB.

Selling a commodity where demand is bigger than supply and the market is free and open, including effective logistics and limited transaction costs, leaves the power to primary producers. Norwegian salmon products (fresh or frozen, whole or fillet) are sold in business-to-business (B2B) negotiations on a weekly basis. Wholesalers from all the main consumer markets (Europe mostly) buy whole truck loads either directly or through Norwegian wholesalers as representatives for a European wholesaler or secondary producer in Europe. It is estimated that around 60% of the volume is sold on such spot market conditions to the highest bidder (Olafsdottir et al., 2019). Trade duration studies show generally short-lived relations between Norwegian salmon exporting firms and their importing partners for the period of study (e.g. Jaghdani et al., 2024). However, there is an emergence of long-term contractual supplier-customer relationships between large aquaculture-producing companies and secondary processors or retailers in Europe (Larsen & Asche, 2011; Olafsdottir et al., 2019). Smaller producers usually do not have direct contractual relations with retailers. This implies that smaller companies may be in a better position to take advantage of the profit opportunities that price volatility offers compared to larger companies that are more likely to be engaged in contracts (Asche et al., 2018). By looking at bilateral transaction cross-sectional price

moments of salmon, rigid pricing is recognized which means prices are primarily revised at fixed time intervals and fixed rates rather than revision based on deviation from the reference price (Oglend et al., 2022). This structure of the value chain has attracted the attention of scholars on price transmission from Norway in an attempt to understand the import markets and the price volatility of salmon prices. For instance, Landazuri-Tveteraas et al. (2018) have shown that for the 2005–2014 period, price transmission was observable between Norway as the exporter and the UK and France as importers for different processed and semi-processed salmon products. They found that major price transmission was evident, with price leadership stemming from export prices to retail prices. In another attempt, Svanidze et al. (2023) tested the price transmission between Norway as the exporter and France as the major consumption market on one side and Poland as the major processing hub by using weekly data from 2017 to 2020. They found supplier-driven price determination with different levels of efficiency for both importing markets. This supplier-driven price transmission is another sign that market imperfection could also be an issue on the supplier's side. However, the results of price transmission studies alone do not substantiate the existence of market imperfection. Finally, Straume, Asche, Landazuri-Tveteraas, et al. (2024) tested the price transmission between retail prices in 20 different retail prices covering France, Germany, Spain and the UK markets for different salmon products (fresh whole, fresh fillet, fresh steak/fish meat, frozen steak/fish meat, prepared fresh ready main meal, smoked fresh) and Norwegian export prices. They found a high degree of price transmission for the less processed consumer products in all markets, while the price transmission is zero for most highly processed products.

Another observed phenomenon in this market is the rise of price volatility for exporter prices during recent years, which has increased the instability in the global salmon supply chain (Asche et al., 2019). The reduced short-run elasticity of supply is considered a primary reason for the rise in price volatility, which, according to Asche et al. (2019), was a result of the rise in concentration, a fixed harvest schedule and regulatory limits on the expansion of salmon harvesting. They argue that the availability of smaller producers is crucial for reducing further volatility increases. The available export price data from SSB shows that the price volatility has even further increased after the COVID-19 pandemic in 2020. Although one would expect a major incident like a pandemic to severely affect global value chains, the latest available research indicates that salmon export patterns were not affected by the COVID-19 pandemic, which is good news (Asche, Straume, et al., 2022; Straume et al., 2022).

Furthermore, we notice trade disputes in the international salmon trade, as unexpected trade policies were imposed. For instance, the US authorities put anti-dumping measures on Norwegian salmon imports in 1991, which were lifted in 2012 (Reuters, 2012). The imports had been found to be subsidized by the Government of Norway and sold in the United States at less than fair value. During 2010–2016 China's sanctions on Norwegian salmon influenced limited exports to China. However, at the same time, exports to other countries like Vietnam increased (Garcia & Nguyen, 2023). There are also price-fixing allegations against some major Norwegian salmon firms. In an announcement in January 2024, the EU Commission alleged that Norwegian salmon producers breached antitrust rules and colluded to fix spot prices (European Commission, 2024). Also, UK retailers filed a complaint against the same Norwegian firms in 2024 alleging price-fixing of Norwegian salmon (The Competition Appeal Tribunal, 2024). The same allegations in the US and Canada were agreed to settle a class-action lawsuit (CBC, 2023; Reuters, 2022). An import ban on food products that Russia imposed on Western countries after the Crimean crisis of 2014 is still in place. This ban, which includes Norwegian salmon, will probably remain intact, especially following the Russian invasion of Ukraine in 2022. The volatility of international grain markets resulting from Russia's invasion of Ukraine is another external factor impacting the farmed salmon industry. Last but not least, volatility in the oil and gas market can induce depreciation or appreciation in NOK and thus impose market risk on salmon farmers (Benedictow & Hammersland, 2022).

Market imperfections in seafood supply chains

By considering the global development of agri-food supply chains, we can observe that the emergence of powerful food retailers, along with continued increases in concentration among food manufacturers, raises issues of bilateral oligopoly and countervailing power in the wholesale market (Sexton & Xia, 2018). A summary and general overview of market power studies in food supply chains can be found in Crespi & MacDonald (2022), Deconinck (2020), Perekhozhuk et al. (2017), Sexton & Xia, (2018) and Sheldon (2017). There are studies which have looked into the impact of producer organizations (POs) on the bargaining power of farmers as primary producers especially in the dairy industry (Cakir & Balagtas, 2012; Koppenberg & Hirsch, 2022; Lee & Van Cayseele, 2024; Perekhozhuk et al., 2015; Sorrentino et al., 2018). Nevertheless, for the case of salmon in Norway, the concern is more on primary producers and the possible rent that can rise due to licenses and defined quotas. The existence of fishing quotas in general and licenses for farmed salmon in particular means that

seafood supply chains deviate from other food value chains in terms of (1) concentration in the food processing industry and (2) the shaping of POs (Flaaten et al., 2017; Holzer, 2015). Therefore, in this section, we look at studies on possible market imperfections in seafood supply chains, including the role of licenses and quotas for primary producers or harvesters, and trade policies against the limited exporters' or retailers' market power.

Since the introduction of individual transferable quotas (ITQs), the potential existence of rent in different seafood supply chains has been studied. The same issue has also been seriously discussed in Norway for farmed salmon (Oglend et al., 2024). For instance, in order to avoid concentration of ITQs for fisheries in the hand of a few entities or individuals, Anderson (2008) suggests a theoretical model of excessive share limits with capacity-based market power to avoid possible monopoly among holders of ITQs. By using a bilateral bargaining model, Blomquist et al. (2015) argue that the 2011 Swedish reform of giving annual nontransferable catch quotas to fishers has just slightly increased their bargaining power over processors. The role of fishers' organizations (FOs) has also attracted some attention. FOs can increase the technical efficiency and productivity of the members on the one hand (Adetoyinbo & Otter, 2022) and they can create rent or increase the bargaining power on the other hand. For instance, Peña-Torres et al. (2019) argue that the distribution of collective fishing share quotas to FOs in Chile could increase the bargaining power of atomized fishers. In Norway, all ex-vessel sales of fish are required to be sold through one of the six sales organizations determined by the geographical location of the catch. These sales organizations set minimum prices to protect the fishers against buyers' exercising market power (Pettersen & Asche, 2020). The holders of ITQs are not the only actors who may have rent. For instance, Abe et al. (2021) studied the first-price sealed-bid auction of the fish-by-fish first hand market in Japan. They estimated the markdown gained by buyers using a structural auction model with a nonparametric method, finding that the auction winners enjoy a considerably high markdown (48% on average) from market transactions for fish. They assign this markdown to information asymmetry on the distribution of rent between harvesters and buyers in the ex-vessel fish market. In another study in Vietnam, Thủy et al. (2019) argue that imperfect competition among middlemen can help ensure that fish stocks are not depleted. Furthermore, they argue that the middlemen with market power can induce higher economic rent for the supply chain. In one supply chain, they found that the middlemen have insignificant market power, and that stock is being over-exploited. In another supply chain, the middlemen were found to have oligopsony power and the stock was higher than the level that produces maximum sustainable yields.

As the farmed salmon industry in Norway expanded, some concerns on possible market imperfection have arisen. Tveterås (2002) is one of the early studies on the then emerging salmon industry. By using firm level data and estimating a cost function, he argues that cost saving is occurring in this industry due to agglomeration externalities. Furthermore, he suggests that for small firms localized in clusters, agglomeration externalities can compensate for internal economies of scale, making them competitive relative to larger firms located outside clusters. In another study, Kvaløy and Tveterås (2008) have used a theoretical model of the average cost (AC) curve to analyze vertical integration in the salmon industry. They conclude that the farming and processing stages in the salmon industry have become more capital-intensive, which has led to a steeper U-shaped average cost (AC) curve. Their model shows that, in the context of a repeated game model of relational contracting, when the AC curve is sufficiently steep, processors and farmers are more likely to vertically integrate. The reason is that steep AC curves make it costly to deviate from the optimal production scale, which in turn makes processors more vulnerable to opportunistic behaviors on behalf of their suppliers.

By considering the development of the salmon industry and available statistics, Asche et al. (2013) have shown that, in Norway, production per license has increased from 26 tons in 1980 to 1130 tons in 2010, suggesting a substantial intensification within the industry. Additionally, they have shown that in all five leading salmon producing countries, the degree of concentration has increased, and the large firms have become bigger over time. Furthermore, Asche and Roll (2013) have shown that technical efficiency has improved over time in the Norwegian salmon industry. They argue that this improvement can partly be explained by a restructuring of the industry, with firms becoming bigger and more specialized, as well as by improvements to government regulations. They consider disease outbreaks as the main cause of inefficiency. By employing production function and stochastic frontier, Roll (2019) showed that insurance has an enhancing effect on salmon farms' production and efficiency and changes the utilized input mix. A well-insured farmer uses more feed and less capital and labor than a less-insured farmer. In another study, Aponte (2020) reported that small firms in the Norwegian salmon aquaculture industry showed higher profitability ratios and revenue productivity than their bigger counterparts for the period 2001 to 2016. He assigned their better performance to the advantage that comes with a flexible harvesting schedule when operating in the spot market. Furthermore, Pincinato, Asche, and Roll (2021) tested the escapee challenge of salmon farmers by using a multi-output short-run translog cost function for the years 2006. They concluded that escapees do not have direct or indirect effects on production costs. Finally, in one of

the latest studies, Kulmambetova and Tveterås (2025) employed the cost function and accounted for the spatial proximity of farms. They have shown that there are economic welfare effects due to the farm location structure and the spatial biological externalities between farms.

The limited number of salmon exporters has encouraged studies on market imperfection in the salmon trade. As one of the early studies, DeVoretz and Salvanes (1993) have used the price discrimination model to analyze the supply-demand equilibrium of the salmon market. Using Norwegian salmon trade data from 1983 to 1988, they show that Norwegian exporters had a limited ability to engage in regional price discrimination. Nevertheless, seasonal price discrimination may have taken place because demand was more inelastic in periods when fresh wild-caught salmon were unavailable. The development of the salmon industry and its supply chain has also been studied in other parts of the world with a focus on other actors in the supply chain. Xie and Zhang (2014), for example, studied the level of competition in the US salmon import market using a residual demand model. Monthly trade data between the US, Chile and Canada from January 1995 to December 2012 were applied for this estimation using residual demand elasticity (RDE). Norwegian salmon was subject to an import ban in the US market over this period. The estimation results explain the jointly dominant positions of Chilean and Canadian salmon exporters in the US salmon import market. Additionally, estimation results indicate that the profit margin of Canadian whole salmon was substantially higher during the period when the antidumping order (AD) measure was imposed on Chilean salmon and after the infectious salmon anemia (ISA) outbreak.

The exercise of market power in the UK salmon supply chain has been studied thoroughly. Using non-linear three-stage least squares to estimate a dynamic error correction model (ECM), Jaffry et al. (2003) have studied the competitiveness in the UK retail salmon market. They conclude that the market is competitive in both the short and long run. Fofana and Jaffry (2008) used the average quarterly 1992–2004 prices for smoked, filleted, and whole salmon at the retail and wholesale level in the UK to test oligopsony power in the chain. This was in response to concerns about increased concentration in the UK salmon retail sub-sectors. They used a dynamic error correction translog profit function to model the behavior of retailers in the input market for smoked, filleted, and whole salmon. The final estimated indices of market power in the models were low and statistically significant but sufficiently closer to the perfect competition. And finally by using residual supply elasticity, Asche et al. (2011) tested the hypothesis of the availability of oligopsony power for three key seafood products, cod, salmon and shrimp, without any evidence thereof.

As we can see in the above literature, due to the nature of the salmon supply chain, different hypotheses on rent-seeking behaviors, cost savings and market power abuse can be suggested for this chain. As these studies show, licenses or quotas do not necessarily yield rent or market power abuse and market imperfections can appear in different nodes of a supply chain. This was our motivation for applying a novel market power analysis approach by Kumbhakar et al. (2015) to shed light on the consequences of recent changes in concentration in production, which is accompanied by primary processing in the salmon industry in Norway. We consider the markup to find the possible occurrence of market imperfections in the industry.

Methodology and data

Conceptual framework

We follow the methodology developed by Bresnahan (1982, 1989) and Muth and Wohlgenant (1998) to test for market imperfections. The model is derived using the conjectural variation approach and under the behavioral assumption of profit maximization.

The optimization problem can be introduced as follows. Let's have the profit function of *i*-th producer:

$$\pi_i = p \cdot y_i - C(\mathbf{w}, y_i, t) \tag{1}$$

where *p* is the price of output, *y_i* is the output of *i*-th producer, **w** is a vector of input prices, and *C*(**w**, *y_i*, *t*) is a cost function of *i*-th producer. Time trend (*t*) is a proxy variable capturing technological change.

Using the inverse demand function:

$$p = f^{-1}(y, \mathbf{d}) \tag{2}$$

where **d** is a vector of demand shifters and *y* is the total demand for food, and profit function (see Equation (1)), the first-order condition for profit maximization is given by:

$$\frac{\partial f^{-1}(y, \mathbf{d})}{\partial y} \cdot \frac{\partial y}{\partial y_i} \cdot y_i + p - \frac{\partial C(\mathbf{w}, y_i, t)}{\partial y_i} = 0 \tag{3}$$

Moreover, rewriting Equation (3) in terms of elasticities we get:

$$p \cdot \left(1 + \frac{\Omega}{\varepsilon_p} \right) = \frac{\partial C(\mathbf{w}, y_i, t)}{\partial y_i} \tag{4}$$

where $\varepsilon_p = \frac{\partial y}{\partial f^{-1}(y, \mathbf{d})} \frac{p}{y} < 0$ is a demand elasticity of the output and $\Omega = \frac{\partial y}{\partial y_i} \cdot \frac{y_i}{y}$ is a conjectural elasticity. The conjectural elasticity is an indicator of the degree of market power. The elasticity lays in the interval $\Omega \in [0; 1]$.

Whereas $\Omega = 0$ represents competitive behavior and $\Omega = 1$ characterizes monopolistic power. That is, a significant positive value of Ω indicates the presence of noncompetitive behavior in the output market. In particular, the higher Ω is, the greater is the degree of noncompetitive behavior/market imperfections or market power imbalances in general, respectively. The latter can be shown using the relative markup representation (φ), $\varphi = \frac{P-MC}{MC}$ (Kumbhakar et al., 2012).⁶ Čechura et al. (2024) demonstrate that relative markup (φ) is proportional to the indicator of market power (Ω) and can be directly computed when the demand elasticity and the conjectural elasticity are known, see Equation (5):

$$\varphi_{C_MP} = \frac{p^C - MC^{MP}}{MC^{MP}} = \frac{\frac{\partial C}{\partial y} - \frac{1}{(1+\frac{\Omega}{\varepsilon_p})} \frac{\partial C}{\partial y}}{\frac{1}{(1+\frac{\Omega}{\varepsilon_p})} \frac{\partial C}{\partial y}} = \frac{1 - \frac{1}{(1+\frac{\Omega}{\varepsilon_p})}}{\frac{1}{(1+\frac{\Omega}{\varepsilon_p})}} = \frac{\Omega}{\varepsilon_p} \tag{5}$$

which is given when the product price under the situation with market power (p^{MP}) and marginal cost under perfect competition ($p^C = MC^C$) is substituted into the relative markup. Moreover, Equation (4) suggests that:

$$p \geq \frac{\partial C(\mathbf{w}, y_i, t)}{\partial y_i} \text{ for } \Omega \in [0; 1] \tag{6}$$

Following Kumbhakar et al. (2012) and expanding both sides of the Equation (6) by the $\frac{y_i}{C_i}$:

$\frac{py_i}{C_i} \geq \frac{\partial C(\mathbf{w}, y_i, t)}{\partial y_i} \frac{y_i}{C_i}$, and expressing $\frac{\partial C(\mathbf{w}, y_i, t)}{\partial y_i} \frac{y_i}{C_i} = \frac{\partial \ln C}{\partial \ln y_i} = \frac{\partial D^I}{\partial \ln y_i}$, where the last equality comes from the duality of the cost (C) and input distance (D^I) functions (Shephard, 1970), we get:

$$\frac{py_i}{C_i} \geq \frac{\partial \ln D^I}{\partial \ln y_i} \tag{7}$$

Empirical model and estimation strategy

Inequality in Equation (7) can be transformed into equality by adding a non-negative one-sided term, u_i :

$$\frac{p \cdot y_i}{C_i} = \frac{\partial \ln D^I}{\partial \ln y_i} + u_i, \quad u_i \geq 0 \tag{8}$$

Assuming that the input distance function has a translog form, then for one output it can be written as:

$$\ln D^I = \alpha_0 + \alpha_t t + \frac{1}{2} \alpha_{tt} t^2 + \alpha_y \ln y + \alpha_{y_i} \ln y_i + \frac{1}{2} \alpha_{yy} (\ln y)^2 + \alpha'_X \ln \tilde{X} + \alpha'_{X_t} \ln \tilde{X} t + \frac{1}{2} \ln \tilde{X}' A_{XX} \ln \tilde{X} + \ln \tilde{X}' A_{Xy} \ln y \tag{9}$$

where $\tilde{X} = x_j/x_j$ for $j = 1, \dots, J$ is a matrix of normalized inputs, α is the vector of estimated coefficients and A is the matrices of the vector of coefficients.

The corresponding first-order derivative is:

$$\frac{\partial \ln D^I}{\partial \ln y_i} = \alpha_y + \alpha_{yt} + \alpha_{yy} \ln y_i + \alpha'_{Xy} \ln \tilde{X}_i \quad (10)$$

Consequently, a combination of Equations (8) and (10) results in the following markup model:

$$\frac{py_i}{C_i} = \alpha_y + \alpha_{yt} + \alpha_{yy} \ln y_i + \alpha'_{Xy} \ln \tilde{X}_i + u_i \quad (11)$$

The markup model in Equation (11) can be estimated using the stochastic frontier approach that was first applied by Kumbhakar et al. (2012) and later on extended by e.g. Čechura and Jaghdani (2021) or Koppenberg and Hirsch (2021). The final model specification that's used in the empirical part addresses two important issues: (i) the conceptual treatment of the non-negative one-sided error term and (ii) the endogeneity problem in the estimation of the markup model (see Equation (11)).

The first issue is treated using a four-component stochastic frontier model specification (Tsonas & Kumbhakar, 2014). In particular, we append to Equation (11) statistical noise (v) and distinguish between the transient (ε) and persistent (μ) part of the non-negative one-sided error term, i.e. $u = \varepsilon + \mu$. Since the market power is a result of firm strategy, which has a long-run nature, only the persistent one-sided error term can be associated with the market power (Čechura & Jaghdani, 2021). Moreover, considering differences in firms' technologies analogically to random parameters model, α_y is in Equation (11) replaced by $(\alpha_y + \alpha_{y_i})$, where α_{y_i} represents the heterogeneity component in the estimated markup model in Equation (12). The conceptual distinction between heterogeneity, and the transient and persistent one-sided error term is crucial for getting a consistent estimate of relative markup. In particular, the model is misspecified and the results are biased if the model does not contain one or more of these components. Specifically, Kumbhakar et al. (2015) show that the model produces an upward bias of the one-sided error term if firm effects (latent heterogeneity) and the one-sided component are not distinguished. Specifically, the model provides an upward biased estimate of market-up component if the transient and persistent parts of the one-sided component are not treated separately.

The second issue, the endogeneity problem, is addressed using a system of generalized method of moments (GMM) estimator. In particular, we follow Bokusheva and Čechura's (2017) four-step estimation procedure. In the

first step, we apply the two-step GMM system (Arellano & Bover, 1995; Blundell & Bond, 1998) estimator to get unbiased parameter estimates of the markup model. Then, in the second step, the residuals from the GMM level equations are employed in the estimate of the random effects model using the generalized least squares (GLS) estimator. The next steps use a maximum likelihood estimator (ML) to estimate frontier models to provide estimates of transient, persistent and heterogeneity components (see Čechura et al. (2024) for detail estimation through system GMM four-step approach).

To sum up, the model to be estimated has the form:

$$\frac{py_{it}}{C_i} = (\alpha_y + \alpha_{y_i}) + \alpha_{yt}t + \alpha_{yy}lny_{it} + \alpha'_{xy}ln\tilde{X}_{it} + \varepsilon_{it} + \mu_i + v_{it} \quad (12)$$

where subscript $i=1, \dots, I$ refers to the i -th producer and $t=1, \dots, T$ denotes time. The distributional assumptions are as follows: $v_{it} \sim N(0, \sigma_v^2)$, $\varepsilon_{it} \sim N^+(0, \sigma_\varepsilon^2)$, $\mu_i \sim N^+(0, \sigma_\mu^2)$ and $\alpha_{y_i} \sim N^+(0, \sigma_\alpha^2)$. Moreover, these components (v_{it} , ε_{it} , μ_i , and α_{y_i}) are assumed to be independent of each other and of regressors.

The relative markup can be then calculated as:

$$\hat{\varphi}_i = \frac{\hat{\mu}_i}{\frac{\partial \ln D}{\partial \ln y_i}}, \text{ i.e. } \hat{\varphi}_i = \frac{\hat{\mu}_i}{\alpha_{y_i} + \alpha_{yt}t + \alpha_{yy}lny_{it} + \alpha'_{xy}ln\tilde{X}_{it}} \quad (13)$$

Data

The dataset is drawn from two main sources. The list of enterprises was selected from the KONTALI salmon industry reports.⁷ These are the large enterprises, and the small- and middle-sized firms and exporters of Norway's salmon industry. Later, the financial data that's reported by these enterprises was extracted from "Purehelp,"⁸ a major Norway business search engine that compiles reported financial data from companies, for the 2008–2018 period. Moreover, the size of the salmon harvest and number of licenses were extracted from KONTALI reports for different years.

By using the data explained above, we use the following variables in the model: *Revenue share* = Revenue/Costs, *Output (Y)* which is total revenue, and normalized costs of *Material (M)* and *Labor (L)*. Revenue is represented by the total revenue (turnover) of the company. Costs are the sum of *labor costs*, *material costs* and *capital costs*. Labor costs are represented by the costs of employees, material costs by product consumption per company, and capital costs by depreciation. Output is expressed as total revenue (turnover) of the company and is deflated by the sectoral index of food processing prices (2015 = 100) while capital is represented by total

fixed assets. Material and capital are deflated by the index of producer prices in the industry (2015 = 100) and labor by the consumer price index (2015 = 100). Moreover, all variables are normalized by their geometric mean. Finally, since the input distance function is homogenous to degree 1, we impose homogeneity by normalizing material and labor by capital. Then, we avoided producers with zero values of particular input(s) and producers with fewer than four consecutive observations. The latter was done to meet the requirements of the applied GMM estimator. As a result, our sample is an unbalanced panel data set that contains 993 observations and represents the 2008–2018 period. Finally, we employed input variables as instruments lagged up to two periods for the equation in levels and up to three periods for the equation in differences in the system GMM model estimate. Then, year dummies and total fixed assets were used as additional instruments; summary statistics of the main variables are provided in Table 3.

Results

Table 4 provides a parameter estimate of the markup model (see Equation (12)) for salmon producers in Norway. The estimates indicate the overall statistical quality of the model. All fitted parameters are statistically significant at the 5% significance level. Moreover, the Arellano-Bond test for $AR(2)$ in first differences as well as the Hansen test of over identified restrictions show the validity of the model and the employed instruments, respectively. Finally, the results for the second, third and fourth steps of the estimation procedure indicate, in all cases, highly significant estimates of the one-sided error terms. In particular, the statistical significance of the permanent part of the one-sided error component shows that the deviations from the competitive market situations might be important characteristics of salmon producers' output market in Norway. In other words, we can reject the null hypothesis about no market imperfections or perfect competition in the Norwegian salmon market, respectively.

The output and normalized material input coefficients indicate a negative impact on the revenue share. On the other hand, labor inputs positively determine the revenue share, suggesting that the small and middle size companies may be more cost flexible and/or produce for niche markets, in

Table 3. Summary statistics of the main variables (thousands of NOK, adjusted for inflation).

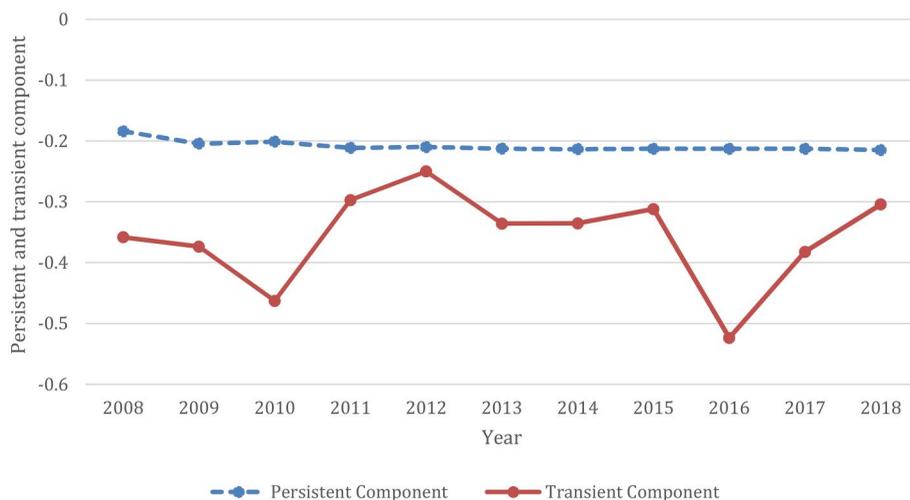
Variable	Obs	Mean	Standard deviation	Minimum	Maximum
Material	993	5174.7	12879.4	2.1	147093.6
Labor	993	448.7	1293.6	0.3	12158.1
Capital	993	2565.1	6986.0	0.1	76177.6
Revenue	993	766249.0	1760122.0	2584.0	16300000.0

Source: authors' estimations with data from Purehelp and KONTALI.

Table 4. Markup model.

Variable	Coefficient	Std.Dev.	P-value
Time (t)	0.0435	0.0112	0.0000
Logarithm of output (\ln_y)	-0.0808	0.0351	0.0230
Logarithm of normalized labor cost (\ln_{nL})	0.1382	0.0634	0.0310
Logarithm of normalized material cost (\ln_{nM})	-0.1521	0.0354	0.0000
Constant	-2.8607	0.5543	0.0000
		Test	p-value
AR(2)		statistics	0.254
Hansen test of overidentified restrictions: $\chi^2(106)$		102.49	0.578

Source: own calculations.

**Figure 7.** Persistent and transient components.

Source: own calculations.

general, have higher revenue share. Moreover, more labor-intensive companies have higher revenue share. The time variable (t) has a positive sign, indicating the increase in added value and profitability of the Norwegian salmon industry, which is in line with the aggregate figures of the industry (see Figure 6). However, as we can see in Figure 6, this varies alongside the increasing trend.

Figure 7 shows both the transient as well as the persistent one-sided component. The transient component provides information on short-run deviations, which can be related to, for example, contract changes and is expected to be volatile through time. It is evident that short-run deviations are a significant characteristic of the sample and if the transient component is a part of the markup, it may result in delivering wrong implications with respect to the size and dynamics of the market imperfections. In other words, these results show the importance of distinguishing between the one-sided error term of the transient and persistent components and of associating only the persistent component as a measure of market imperfections due to its source in company strategy. In addition, the persistent

component shows that the changes in the dataset due to the entry and/or exit of a producer from the dataset (see the unbalanced panel dataset) are not an important characteristic of the studied sample and thus might not have a considerable impact on the markup dynamics and consequent implications. The lower values for the average transient efficiency score in 2010 and 2016 can be assigned to salmon price increases in the international market in 2010 due to disease outbreaks in Chile and the NOK devaluation after 2015, respectively (see [Figures 3](#) and [6](#)).

[Figure 8](#) (panel A and B) indicates certain deviations from the perfect competition, which is characterized by the identity $P = MC$. Similar information on the size and dynamics of the relative markup can be drawn from the weighted markup ([Figure 9](#)) when the size of companies is used as a weight. Based on these results,⁹ we can say that a hypothesis of perfect competition can be rejected. However, as the weighted average range of the relative markup is between 0.31 and 0.19, and that the distribution is skewed to lower values, we can conclude that an abuse of market power may be available only for a limited number of companies and was reduced during 2008–2018. Moreover, assuming that the price elasticity was constant in the period under investigation, then based on the derived equation (5) we may conclude that a decreasing trend in relative markup implies a decreasing trend in market power in the Norwegian salmon industry.

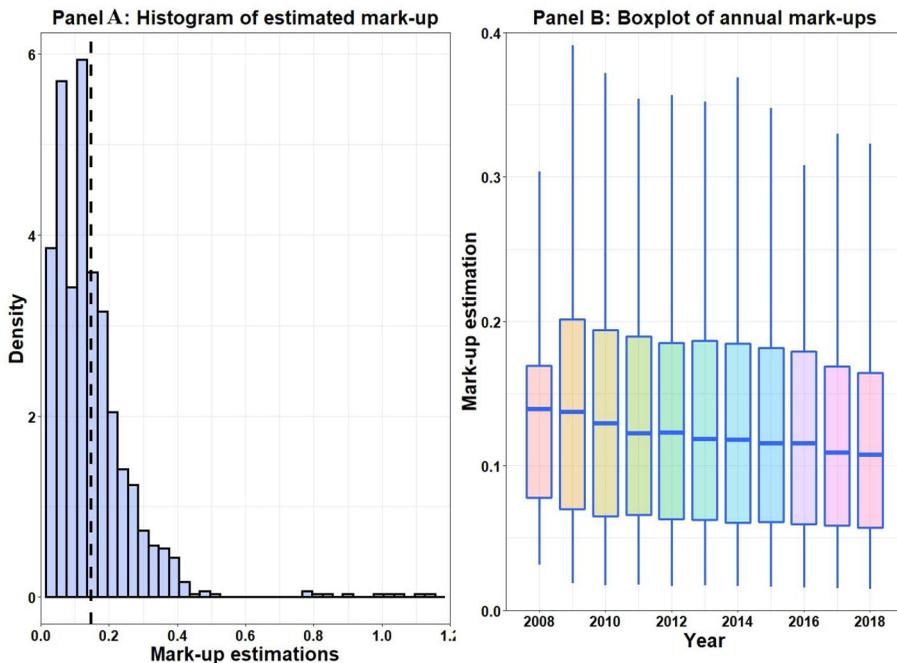


Figure 8. Histogram and boxplot of relative markup.
Source: Own calculations.

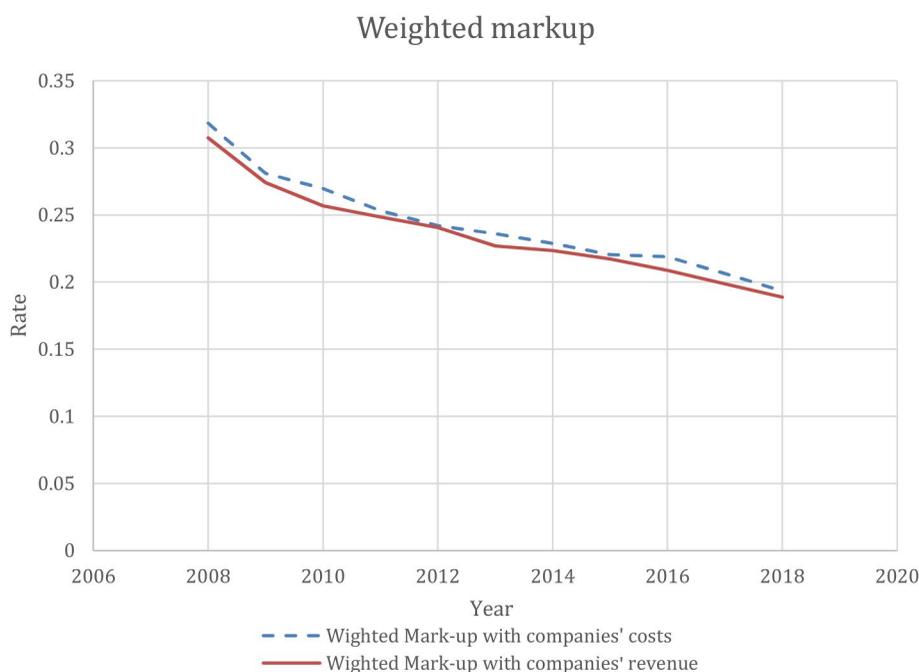


Figure 9. Weighted markup with companies' annual revenue and current costs.
Source: Study findings.

Table 5. Summary statistics of the estimated relative markup.

Minimum	1st Qu.	Median	Mean	3rd Qu.	Maximum
All producers 0.0145	0.0636	0.1200	0.1393	0.1855	0.5037
Middle & Small producers 0.0171	0.0525	0.1166	0.1276	0.1770	0.4222
Large producers 0.0145	0.0776	0.1226	0.1480	0.1929	0.5037

Source: Own calculations.

Table 5 presents the information on the distribution of the relative markup for the whole sample and two size categories, that is small and middle companies and large companies. It shows that the derived conclusions hold for both size categories (small- and middle-sized producers, as well as large producers).

The results of the markup model estimation in Table 5 suggest that small and middle-size companies may exploit economies of scale. This, along with the breakdown of markups in Figure 8, was a motivation for checking the boxplot of the revenue/current cost ratios (dependent variable in Equation (11)) and the markups based on the type of entities in Figure 10. The results of panels A and B in Figure 10 show that, in general, small- and middle-sized companies have a higher revenue share. These graphs show another fact: that the exporters (by considering the nature of their activities) present higher markups with a higher variance. This is another

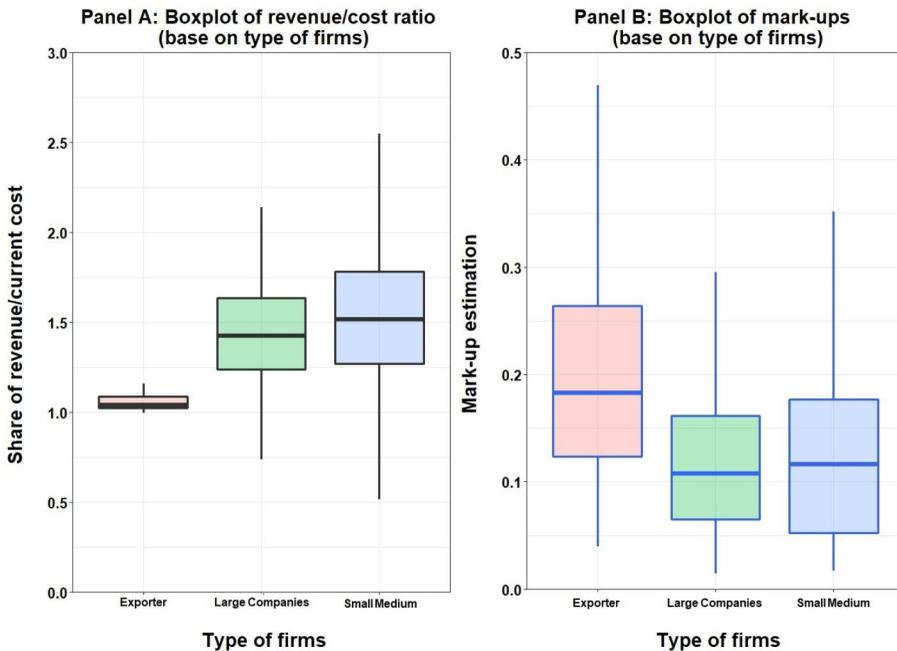


Figure 10. The boxplots of revenue/current cost ratio (panel A) and markups (panel B) considering the type of entities.

Source: Study findings.

argument to support the higher revenue share of smaller firms that are not involved with salmon exports directly.

Conclusion

In this article, we investigated market imperfections in the Norwegian salmon industry at the production and primary processing stages for the 2008–2018 period. We have used firm-level data and applied the markup model by employing the novel methodology of the input distance function. Additionally, we have reviewed the available literature and information on the governance of the salmon supply chain and the level of concentration in this industry at the primary stages to facilitate the interpretation of the markup results. The discussion on imposing rent tax on salmon farmers' value added during sea-based operations on top of corporate tax (Ministry of Finance, 2023) calls for an estimation of the available markups in the industry. Although the tax rate was lowered from an “effective” 35% to an “effective” level of 25% before it was confirmed by the Norwegian parliament, there is still a need for an increased understanding of market imperfection within the industry for researchers, market participants, policymakers and regulators who are involved in the global salmon value

chain. Markup (see $\hat{\varphi}_i$ in Equation (13)) is one of the measures of market imperfections and it signals the existence of rent as there is a complex interaction between concentration in the global food chain, efficiency, and rent distribution (Swinnen & Vandeplass, 2010). The key result of our analysis is that, as expected, a certain level of market imperfection is present in the salmon production industry in Norway, and that there is a small deviation from marginal cost pricing (see Figures 9 and, Table 5). The estimated markup value is a stochastic variable that changes dramatically from firm to firm. Therefore, estimated markups are heterogeneous values across firms. However, as we can see in the historical weighted markup model (Figure 9) and annual changes in markups (Figure 8, panel B), this markup is reduced on average. As Figure 5 shows, the level of concentration in the Norwegian salmon industry is stable and not critical. Even with a reduced number of firms and a higher concentration of licenses in the hands of fewer firms in the period after 2000 (see Figure 4 and Table 1), the markups are not very high and in fact reduce from 31% to 19% for the period of study (2008–2018). It seems that the increase in total licenses contributed to a more competitive market environment in the period under investigation as the markup reduced in the same period.

By looking to the price and market developments between 2008 and 2018 (see Figure 6) that are accompanied by devaluation of the NOK (Benedictow & Hammersland, 2022), the reduction in estimated market imperfection indices (markups in this case) can be assigned to the increasing cost of salmon production as explained by various industry reports (EYGM, 2019; KONTALI, 2019). Based on the data they contain, the average earnings before interest, tax, depreciation, and the amortization (EBITDA) margin have reduced since 2015. This is reflected in the breakdown of the estimated t coefficient that we have presented in the results (see the explanation of Table 4) and variations in costs and revenues in the industry in fixed values (see Figure 6). This development is assigned to an increase in the cost of production and processing. It can be said that this margin reduction can be interpreted to the diminishing of market imperfections for salmon production and for primary processing firms in Norway after 2014. Aponte and Tveterås (2019) have also recognized the increase in production costs after 2005. Another event of interest that we must consider is the Russian import ban of August 2014 when Russia had 10% of the Norwegian salmon market. This event seems to have had a negligible effect on the salmon market. Later, the nominal price of salmon increased simultaneously with the devaluation of the NOK. By considering the reduction of EBITDA, which was observed and reported on after 2015, we can conclude that increases in the price of salmon have not covered the increasing cost of production/processing.

Therefore, it can be said that any potential cost-efficient disease-fighting technological developments that may appear in the future would decrease the cost of production/processing. However, this should be investigated by future research.

Our results for the 2008–2018 period are in line with Tveterås (2002) and Aponte (2020) who found that smaller firms were competitive relative to larger firms and have higher profit ratio. As Figure 10 shows, we found slightly higher margins and markups for small- and medium-sized firms. Another finding was higher markups for exporters despite having lower revenue to current cost margins. This signals the potential existence of rent mainly on the side of middle entities such as exporters, who often belong to large vertically integrated salmon companies. However, it seems that such considerable rents are not available for the salmon producing and processing industry stages to justify the Norwegian government's initial plan of 40% rent tax. As was mentioned, the heterogeneous nature of markups shows that additional taxes can put the profitability and survival of many medium sized (or even small) firms in this industry in jeopardy (considering the conditions defined for taxing the firms). This extra rent tax can cause lower investments in advanced and cost-saving technologies, eventually preventing this group of more efficient small or medium firms to grow (see Misund et al. (2025)). We have shown that for the period of study, small- and medium-sized firms with higher labor intensity may be more cost-flexible and/or produce for niche markets. However, if those small or medium-sized firms fall in the tax-paying category, labor employment may be affected. The way that the rent tax is defined may encourage producers to show higher costs and lower profits through innovations in accounting values which is more effective for larger firms (see Misund et al. (2025)). Furthermore, as mentioned in the results, possible market abuse is not available among all firms in this industry, but only among a limited number which has been reduced since 2008. As the tax will not only directly affect most salmon farmers, but also most certainly indirectly impact the rest of the industry, the total impact remains to be seen in the coming years. Finally, by considering our estimation on concentration rate, heterogeneous level of estimated markups, and the higher level of markups for small and medium size companies, we cannot assign this market imperfection to concentration. Additionally, we cannot reject the fact that the estimated markups in this analysis may reflect the available economic rent due to regulatory rent (as discussed by Oglend & Soini, 2020) or quasi rent or inframarginal rent (see Misund & Tveterås, 2020) in Norwegian salmon aquaculture industry. The methodology that we have employed in this study does not let us to find the exact source of rent as listed above.

Although, after strong backlash from major industry players, the Norwegian government's initial proposed tax rate of 40% was lowered to an "effective" 25% before approval, the new tax has caused a lot of uncertainty within the industry. As we have presented in this study, small- to medium-sized firms may also be affected by such a decision, as some benchmarks are defined for profitability levels. Furthermore, the motivation for investment on advanced and cost-saving technologies may be eradicated, as most of the industry will be affected by the tax proposal. We suggest that market imperfections should be considered more seriously for further decisions on tax levels in this industry.

Notes

1. Since rent-related corporation tax is deducted from the rent tax base, a formal tax rate of 32.1 per cent will correspond to an effective tax rate of 25 per cent (Ministry of Finance, 2023).
2. More about discount on the wealth tax value: <https://www.skatteetaten.no/en/rates/wealth-tax/>.
3. We have used whole fish equivalent (WFE) which is used by the Directorate of Fisheries in this graph. Nevertheless, there are different measures for Fish weight. As mentioned by Misund (2022, p. 22): "Live fish weight (LW) is the weight of the fish before starving and bleeding (6–8 per cent weight loss). Subtracting these weight losses gives whole bled fish or whole fish equivalent (WFE). The Directorate of Fisheries uses whole fish weight as a standard measure, as does FAO in its figures for aquaculture production. Gutting results in an additional 10% weight loss. Head on gutted (HOG) is the weight measure used for salmon prices, both by Statistics Norway and Nasdaq. Gutted weight is also preferred by financial analysts."
4. SSB refers to *Statistisk sentralbyrå* (in Norwegian) or *Norwegian Statistics Bureau*.
5. The CR_m is estimated as $CR_m = \sum_{i=1}^m s_i$ that s_i shows the market share of i^{th} firm as one of the top m major firms in the collection of total n firms in that industry ($m \leq n$) (Kvålseth, 2018).
6. Relative mark-up (φ) measures the percent deviation of the product price from the marginal cost. The relative mark-up has the following relation to, in the literature well known, Lerner index (Lerner, 1934): $L = \frac{P-MC}{P} = \frac{\varphi}{1+\varphi}$.
7. <https://www.kontali.no/publications/yearly-publications#salmon-farming-industry-in-norway>
8. www.purehelp.no.
9. To recall, the mark-up is in the interval $L \in (0,1)$, 0 indicating that competitive behaviour and market imperfections increase with increasing mark-up index.

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