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Production growth, company size, and concentration: The case of salmon☆

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ABSTRACT

The largest companies in salmon aquaculture are rapidly getting bigger due to organic growth as well as mergers and acquisitions, and the largest are now multi-national companies. There are two main explanations for this growth: 1) An attempt to become large enough to exploit market power, or 2) Size is necessary to adopt new technologies that increase the efficient scale. In this paper, we investigate the degree of concentration in each of the main producer countries for Atlantic salmon, as well as globally for Atlantic salmon, all farmed salmon, and all salmon to account for the global nature of the market using Herfindahl-Hirschman Indexes. The results indicate a high degree of concentration in the smaller producer nations but not in Chile and Norway. Globally, the Atlantic salmon industry can be characterized as unconcentrated, and it becomes even more so when the supply of other farmed salmon and wild salmon is accounted for. Hence, the main motivation for the increased company size appears to be capacity to adopt new knowledge and technology.

1. Introduction

Globally, aquaculture production continues to be rapidly growing, and in an increasing number of countries (Garlock et al., 2020, 2022a; Naylor et al., 2023). The main drivers of this development are adaptions of knowledge from the agro-sciences and innovations that improves productivity and make aquaculture producers more competitive (Asche, 2008; Kumar and Engle, 2016). However, while we have significant knowledge with respect to which species are produced and in which countries, our knowledge with respect to the companies that are producing this seafood is limited beyond the fact that there is tremendous variation from small-scale subsistence farms to multi-national companies producing more than 100,000 metric tons (mt) (Asche et al., 2013; Cojocaru et al., 2022; Naylor et al., 2023). We also know that in some industries, there are strong indications of consolidation (Nielsen et al., 2016; Llorente et al., 2020; Ankamah-Yeboah et al., 2021; Engle et al., 2022), but there are few attempts to describe this process over time. Asche et al. (2013) is a partial exception by showing how many companies make up 80% of the Atlantic salmon production in the main salmon-producing countries as well as providing concentration measures for 2010.

In general, there are two economic explanations for increased firm concentration (Morrison-Paul, 2001). One is that larger companies have more capacity which is used to increase their competitiveness as they reduce production costs. This is beneficial in a larger perspective as lower production costs tend to be passed on to the consumers in the form of lower prices in competitive markets. Capacity may be technological as many improved technologies are not size independent, and therefore, technology development can provide incentives to increase company size (Tveterås and Battese, 2006; Asche et al., 2013). Capacity may also be related to marketing and logistics of the products as larger companies tend to be more able to invest in customer specific relationships (Kvaløy

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and Tveterås, 2008; Asche et al., 2018), and even the ability to improve input purchasing practices (Naylor et al., 2023). The other explanation is that companies with a dominant position in the supply chain can increase their profits by controlling the supply of the product, that is, the company is able to exercise market power. This is negative for society in general, as it leads to higher prices. In many countries there are laws meant to prevent a so high degree of concentration that exploitation is possible enforced by anti-trust authorities. There is also a non-economic explanation for why larger companies are problematic as these are perceived to have smaller local impacts (Phyne, 2010; Young et al., 2019).[1] This is a reason why ownership often is restricted in fisheries (Cojocaru et al., 2022; Garlock et al., 2022b; Kroetz et al., 2022), while this is less common in aquaculture with Norway as a notable exception (Asche and Bjørndal, 2011).

In this paper we will investigate the development in firm concentration in salmon aquaculture from 2011, the first year with available data that allow this form of analysis. Firm concentration in salmon aquaculture is interesting for a number of reasons. In the global aquaculture industry, salmon aquaculture is technologically leading in a number of dimensions (Smith et al., 2010; Asche et al., 2018; Afewerki et al., 2023), and the firm structure may be an important explanatory factor. We know that economies of scale are important in salmon farming at the farm level (Roll, 2019; Roch-Aponte and Tveterås, 2019; Rocha-Aponte, 2020; Pincinato et al., 2021), that the size of individual farms has increased (Asche et al., 2013; McIntosh et al., 2022) and that there are industry clusters (Tveteras, 2002; Tveterås and Battese, 2006; Asche et al., 2016; Gaasland et al., 2020).[2] In addition, many of the larger salmon-producing companies are operating a number of farms, and some are also multi-national companies, potentially facilitating international technology adoption (Kumar et al., 2021; Osmundsen et al., 2021) as well as global marketing strategies (Cojocaru et al., 2021; Asche et al., 2022a) and spreading risk (Oglend and Tveteras, 2009).[3] The largest salmon companies are among the largest seafood producers in the world as several companies have a production of over 100 thousand mt in 2020, and Mowi may well be the world's largest seafood producer and not only the largest salmon producer. Several of the largest companies are listed at stock exchanges (Misund and Nygård, 2018; Sikveland et al., 2022). There have also been a number of trade conflicts associated with salmon in the U.S. and the EU where firm structure is important (Asche, 2001; Kinnucan and Myrland, 2002, 2006), and there has recently been an investigation of the pricing practices of largest Norwegian companies by U.S. authorities and there is an ongoing investigation in the EU (Intrafish, 2023).

Atlantic salmon is a global species in consumption (Straume et al., 2020; Oglend et al., 2022), but only five countries make up more than 90% of the production (Iversen et al., 2020), making an investigation at the firm level tractable. Our main approach in this paper is to compute Herfindahl-Hirschman Indexes (HHIs) to measure the degree of concentration. At the country level, we will also use as a secondary measure the concentration ratio (CR), i.e., the combined production share of the four largest companies. These measures will be computed in each of the five main production areas as well as globally for Atlantic salmon. Given that there is strong evidence of a global market for salmon (Anderson et al., 2018; Landazuri-Tveteraas et al., 2021; Salazar and Dresdner, 2021; Roll et al., 2022) the global measure will be the most important.

Moreover, while there has been most focus on the importance of firm structure for Atlantic salmon, other salmon species are also farmed, and wild salmon is also a part of this market. We will therefore also construct HHIs accounting for salmon from these sources.

This paper is organized as follows: In the next section, an overview of global salmon production will be given together with a description of our data sources. In Section 3 the methodology will be presented, followed by the empirical results. The final section concludes.

2. Global Salmon production

Global salmon production, including both farmed and wild, has doubled from 1.89 million metric tons (mt) in 2000 to 3.8 million mt in 2020, where virtually all the growth is due to farmed salmon. Landings of wild salmon vary around a stable mean at 906 thousand mt for the period 2000 to 2020 (Fig. 1), implying that as recently as the early 2000s, wild salmon made up almost 50% of the total quantity of salmon available and it is still making up about 25%.[4]

In terms of quantity, the largest salmonid species is farmed Atlantic salmon, with a production of 2.7 million mt in 2020. Atlantic salmon made up 71.4% of total salmon production in 2020, up from 47.3%. in 2000. The second largest category is wild salmon, which made up 16.6% of total production in 2020, down from 37.9% in 2000.[5] However, it should be noted that the landings in 2020 (and 2000) was unusually low at 633,594 mt compared to an average for the period of 906 thousand mt. The share of wild salmon in 2019, a more normal year, was 24.3%. Farmed salmon trout (large red fleshed trout raised in sea pens) and coho both made up 5.8% of the production in 2020.[6] Farmed chinook production was very small at 15.1 thousand mt making up only 0.4% of total production. In 1980, the production was dominated by wild salmon, and farmed trout production was as large as farmed salmon production (Asche and Bjørndal, 2011; Landazuri-Tveteraas et al., 2021). The share of Atlantic salmon has increased over time for several reasons where the most important appears to be that it is less costly to have it available for the market at all times of the year and therefore can be marketed as fresh, never frozen year-round, in contrast to the other species that are mostly marketed as frozen (Asche and Bjørndal, 2011). Love et al. (2023) show the importance of adjusting to demand in the U. S. market.

Although the production of farmed Atlantic salmon has increased, it is produced in significant quantities in only a few countries - Norway, Chile, the United Kingdom, Canada, and the Faroe Islands make up 90% of the production. This is largely due to biophysical factors as the salmon requires cold water temperatures and with the net-pen technology, a

[1] Social impacts are an important consideration in salmon aquaculture (Ceballos et al., 2018; Cárdenas-Retamal et al., 2021), as well as in other aquaculture industries (Filipski and Belton, 2018; Cojocaru et al., 2022; Naylor et al., 2023)

[2] Increasing farm size is a general phenomenon as shown e.g. by Fernández-Sánchez et al. (2022), Mitra et al., (2022), Rahman et al., (2022), Naylor et al., (2023) and Le Ngoc et al., (2023).

[3] Fischer et al., (2017) argue that the disease dynamics may also give incentives to exploit market power for multi-national companies.

[4] How wild this salmon is can of course be discussed as hatchery programs are important in Alaska, Canada and Japan. Klinger et al., (2013) and Garlock et al., (2022b) argue that this makes it a form of aquaculture as a part of the production process is controlled.

[5] Farmed trout is interesting in that it comes in two clearly distinguishable forms. There is a significant industry in a number of countries producing portion sized white fleshed trout in freshwater plants (Guillen et al., 2019). This fish is not a part of what is commonly labeled as the salmon market that consist of red fleshed larger fish (Nielsen et al., 2007; Bronnmann et al., 2016). The large red fleshed rainbow trout with a grow-out phase in sea pens, on the other hand, is a part of this market (Landazuri-Tveteras et al., 2021)

[6] With the exception of trout, there is wild production of all the farmed salmon species. For Atlantic salmon it is minuscular, for coho wild landings is less than 10% of farmed production, while for chinook the wild salmon is smaller than the farmed production in all but three years in the mid 2000s. The main wild species by quantity with average landings in 1000 mt in the parenthesis are pink (408), chum (310) and sockeye (153). In general, sockeye is the most valuable wild species because of a significantly higher price than chum and pink (Asche et al., 1999; Ray et al., 2022). Chum and pink salmon are also important in the Chinese re-exports of seafood in contrast to the farmed and other wild species (Asche et al., 2022b).

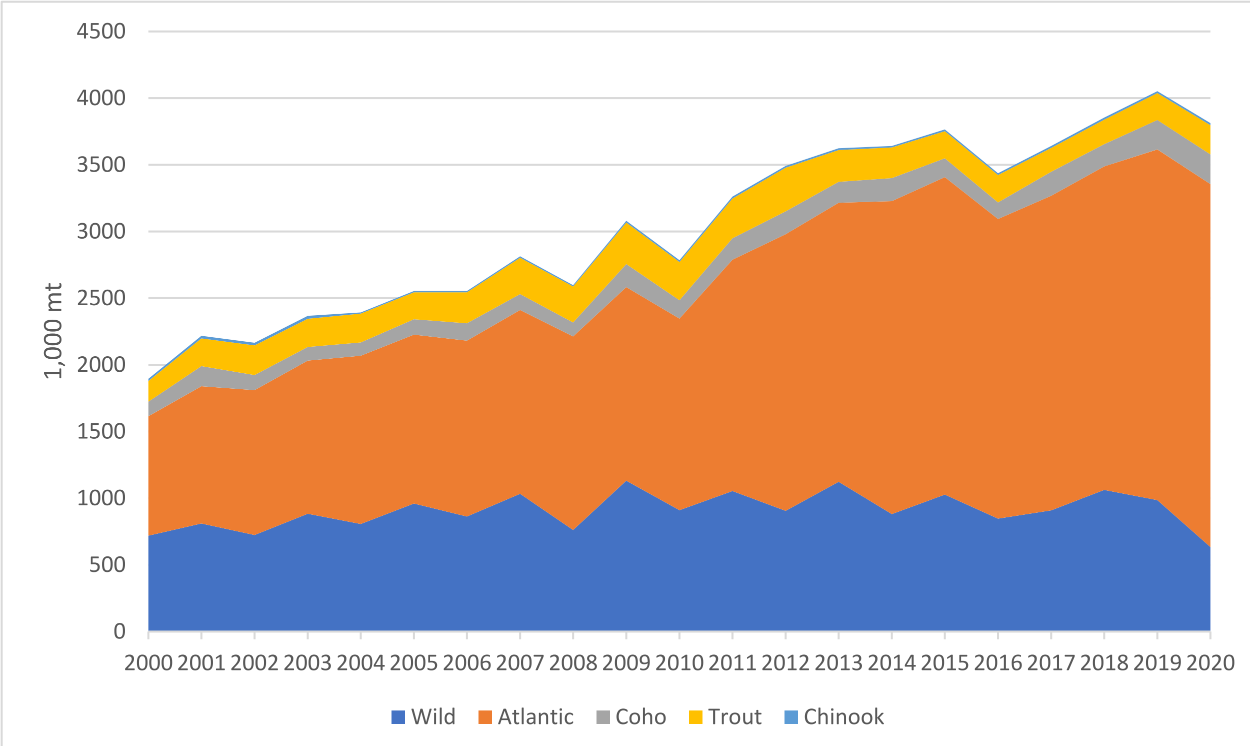

Fig. 1. Global salmon production by farmed species and wild, 2000–2020.
Source: (FAO, 2023)

sheltered coastline.[7] Fig. 2 shows global farmed salmon production by country for the five largest countries as well as an aggregate category for all other countries. Norway is the largest producer and is responsible for over half the total production (51%) in 2020. Most of the production is Norwegian production is Atlantic salmon 1,232,200 mt, but Norway also produced 93,111 mt of salmon trout in 2020. The share of the trout has been gradually declining over time (Landazuri-Tveteraas et al., 2021). Chile is the world's second-largest producer of farmed salmon, supplying around 25% of the global salmon production. In 2020, Chilean salmon and trout production totaled 1,079,595 metric tons (mt). Of the total Chilean production, 787,131 mt was Atlantic salmon (72.9%), 204,740 mt was coho (19.0%), and 87,724 mt was trout (8.1%). Chile is the only significant producer of coho and is the largest producers of trout with Norway as the only other significant production country. With production shares in parentheses, the United Kingdom (7%), Canada (4%), and the Faroe Islands (3%) round out the five leading producer countries. The main producer countries of wild salmon are the USA, Russia, Japan, and Canada, all have some salmon aquaculture production, but with the exception of Canada, in very limited quantities.

Seafood markets have become increasingly globalized since the 1980s (Anderson et al., 2018), and salmon has been a leading species in this process. Asche et al. (1999) showed that farmed fresh Atlantic salmon and frozen wild Pacific salmon have a common price determination process, and that in the long-run the prices of all the species are determined by the production cost for farmed salmon. A number of studies has expanded on this showing that all the salmon species have a common price determination process that includes all product forms. Landazuri-Tveteraas et al. (2021), Salazar and Dresdner (2021) and Roll et al. (2022) are some recent additions to this literature.

Salmon aquaculture is a controversial industry due to its environmental impact as the main production process takes place in open net pens (Osmundsen et al., 2020; Pincinato et al., 2021; Naylor et al., 2023). This has made the industry highly regulated in all countries where it is practiced, and typically a license is required to be allowed to produce together with an environmental assessment at the specific location (Hersoug, 2021), and at the Faroe Islands and in Norway ownership of licenses has been restricted (Hersoug, 2021; Bjørndal, 2023). Until 1991, the Norwegian industry was an owner-operated industry as one could only have a majority interest in one farm. After this severe ownership-regulation was lifted, a restriction on the maximum share of the production licenses a specific company could own was maintained with several adjustments until it was lifted completely in, 2015 (Lovdata, 2015).[8] This led to larger firms being formed earlier in other countries, and for a long time the Scottish firm Marine Harvest was the world's largest salmon producing company (Asche et al., 2013).[9] It should also be noted that there is still a focus on ownership structure when new licenses are awarded, and although environmental issues have become more important, there is still a focus on regions and company type (Hersoug et al., 2021). At the Faroe Islands, ownership restrictions was relaxed earlier, and the only current restriction is on foreign ownership (Bjørndal and Tusvik, 2019).

3. Methods

The most common measure for investigating industry concentration is a Herfindahl-Hirschmann Index (HHI). This is an index which is often used by trade and competition regulators such as the US Department of Justice (US DOJ) for their initial analysis of whether concentration in an

[7] There are interesting attempts at finding alternative technologies partly of environmental reasons and partly due to high profitability (Bjørndal and Tusvik, 2019; Osmundsen et al., 2022).

[8] Hersoug (2021) provides an overview of the development of the Norwegian management system for salmon.

[9] Marine Harvest was merged with the Norwegian company PanFish in 2007, and continued under the name Marine Harvest until 2019, when the company name changed to Mowi.

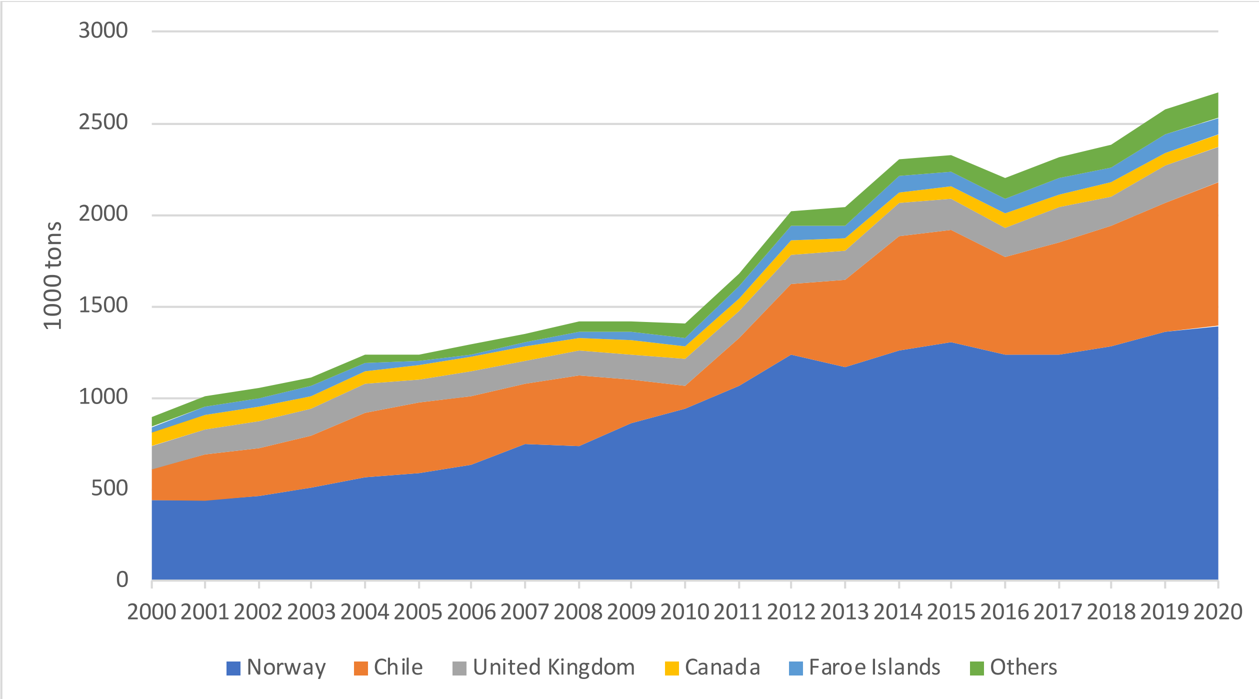

Fig. 2. Global Atlantic salmon production by country, 2000–2020.
Source: (FAO, 2023)

industry is large enough to be a concern.[10] However, it is also used to measure the degree of concentration in other settings such as in quota ownership (Byrne et al., 2020), the relative importance of fishing communities (Cojocaru et al., 2019), diversity of seafood consumption (Love et al., 2022a, 2022b) and export market concentration (Straume et al., 2022).

The HHI is calculated as the square sum of squared shares:

$$HHI = \sum_{i=1}^{n} S_i^2$$

where S_i is the market share of company I and n is the number of companies in the industry. We will use a firms share of production as a measure of the market share. If the market consists of only one company (i.e., market share of 1 or 100%), the HHI index is 1 (or alternatively 10,000). A market consisting of 10 companies each with equal shares, will have a HHI of 0.1 (alternatively 100). The US DOJ considers markets with HHI's between 0.15 and 0.25 to be moderately concentrated, and markets with HHI's above 0.25 to be highly concentrated. Markets with a HHI below 0.15 are considered unconcentrated.

The concentration ratio for up to j firms, CR_j, is computed as the sum of market shares S_i for the j largest firms, i.e., $CR_j = \sum_j S_i$, and we provide it for the four largest companies in each country, i.e. CR_4.

The aggregate production data in this paper is from FAO (FAO, 2023). Firm data is notoriously hard to come by, but as the industry has been growing and an increasing number of companies are being listed on stock exchanges (Misund and Nygård, 2018; Nygård, 2020; Sikveland et al., 2022; Zhang and Tveterås, 2022), more information is gradually becoming available. Data for Norway are relatively straightforward to obtain from the Directorate of Fisheries for all companies. In 2020 there was 102 commercial salmon producers, of which 12 produced only trout, 10 produced both trout and salmon and 80 produced only salmon. In 2011, there was a total of 111 companies. Mowi's Salmon Industry Handbook (Mowi, 2021) provides production data for Atlantic salmon for the largest companies in all the main salmon producing countries. In Chile it contains data for 10 companies making up 87% of the production. Production is reported for North America rather than Canada as Cook Aquaculture is the only company producing Atlantic salmon in the USA, and the four companies that information is provided for in North America makes up 97.1% of the production.[11] In the United Kingdom it provides information for 5 companies making up 95.6% of the total production, and in the Faroe Island information is provided for two companies allowing us to deduce the production of the third company.

Globally, Mowi is by far the largest company, as shown in Table 1. Five of the largest companies have their headquarter in Norway, four in Chile and one in Canada. Five of the companies are producing salmon in more than one country making them multi-nationals, and Mowi is producing salmon in all the five main producer countries.

The production of companies that are not listed in Mowi (2021) are

Table 1
The world's largest Atlantic salmon producing companies in 2020.

Rank	Company	Production (mt)	Headquarter
1	MOWI	431,890	Norway
2	Aquachile	154,800	Chile
3	Salmar	150,300	Norway
4	Cermaq	143,500	Norway
5	Lerøy Seafood	142,900	Norway
6	Grieg Seafood	86,900	Norway
7	Salmones Multiexport	85,200	Chile
8	Cooke Aquaculture	82,000	Canada
9	Salmones Blumar	59,800	Chile
10	Australis Seafood	59,500	Chile

Source: Mowi (2021).

[10] https://www.justice.gov/atr/herfindahl-hirschman-index

[11] For most of these companies in Chile and Norway, the production data is also available from their annual statements.

all smaller than the smallest reported company in each country. To address this missing data issue in all countries but Norway, we use data from companies' annual statements when available and we follow Asche et al. (2013) and assume that the reminder of the production in each country is made up of companies of the same size as the smallest reported company and allocate the remaining production evenly to companies of this size. This means that we estimate that there are 5 more companies than what is reported in Mowi (2021) in Chile and one in respectively North America, the United Kingdom, and the Faroe Islands. This approach will overestimate the HHI as we know that our assumption will indicate that there are fewer companies than what there actually is, and these companies will be estimated to be larger than they actually are. This is not likely to have a significant impact for our global HHI or in the largest salmon producing countries (Norway and Chile), and with the large share of the production covered by the data, the potential bias for the remaining countries is also limited. This approach is also used to allocate salmon to companies in other countries as well as for coho and trout. We estimate there is 27 producers of Atlantic salmon in other countries. For trout and coho we estimate that there are 9 producers in addition to the 17 we have data for.

To account for the wild salmon, we find the average landings per vessel using data from Alaska (ACFEC, 2022). The fleet consists of a large number of small vessels and similar harvesting techniques are used in all salmon fishing countries so that e.g., Valderrama and Anderson (2010) assume that the fishery can be fairly analyzed using a representative vessel. Using this approach gives us 1521 vessels participated in the global wild salmon fisheries in 2020. Dividing the number of the vessels by the total landings should provide a reasonable estimate of the production share of a representative vessel. However, this will slightly underestimate these components of the HHI, given that there is some variation in vessel size.

4. Concentration for Atlantic salmon

In Fig. 3 the HHIs are shown for the five largest Atlantic salmon producing countries and in Fig. 4 the CI_4 is shown for the four largest producer countries. Two obvious conclusions are clear. There is significant variation in the HHIs by country, and for all countries, they are relatively stable. North America is the only region where the degree of concentration has increased somewhat, while there is a very little movement for the four other countries. Not surprisingly, the by far highest HHI is reported for the Faroe Islands, where only three companies are active and where the largest, Bakkafrost, makes up about 75% of the production. The degree of concentration was relatively similar in North America and the United Kingdom in the early 2010s, but the increased concentration in North America clearly separates the two regions in 2020 when the HHI is 0.29 for North America and 0.22 for the United Kingdom. For Norway and Chile, the degree of concentration is relatively similar and moderate at about 0.1. There is some variation in the HHI for Chile as disease and algea blooms impact companies disproportiionally, and a small increase in the concentration towards the end of the period due to mergers. The HHI for Norway is slightly declining over the period, indicating that new licenses disproportionally are awarded to smaller companies (Hersoug et al., 2021).

The CI_4's in Fig. 4 gives a similar picture. It is not shown for the Faroe Islands, as with only three companies, it is always 1. In North America and the United Kingdom, the CI_4 is high of the four largest companies. Dominates production, and in North America also, the CI_4 is increasing somewhat. In Norway, the CI_4 is very stable at about 0.5 over the whole period. In Chile, it started lower at 0.4 in 2011; it varies more and increased from 2017 to 0.52 in 2020.

Overall, the degree of concentration is inversely related to the production level of the various countries. This suggests that a relatively large firm is necessary to exploit the scale economies in production, and there is then room for only a few companies in the smaller producer countries. This is a feature that has only been investigated in detail in Norway due to data availability. Most recent studies indicate that there are still scale economies to be exploited (Roll, 2019; Roch-Aponte and Tveterås, 2019; Rocha-Aponte, 2020). However, this is a feature that appears to change over time, as Asche and Roll (2013) reported constant returns to scale. It would not be surprising if new technologies also increase the efficient scale of operation. For instance, the pen size has gradually increased from less than 5 m in diameter in the 1970s to over 50 m today due to improved materials used in the construction of the pens (Føre et al., 2022; Afewerki et al., 2023). This implies that more than one license is necessary to efficiently operate a farm, something that would not even have been possible with the ownership restrictions in Norway until 1992. The recently introduced offshore farm, a new technology put into operation by the company Salmar in Norway is also the largest single farm (Osmundsen et al., 2022). Also in other areas, scale has increased such as harvesting plants as the harvesting and processing process is becoming increasingly automated (Asche et al., 2018). This is a development that indicates that new technology creates incentives for consolidation and is a feature that is in line with what one has observed in other industries, such as meat packing (Morrison-Paul, 2001).

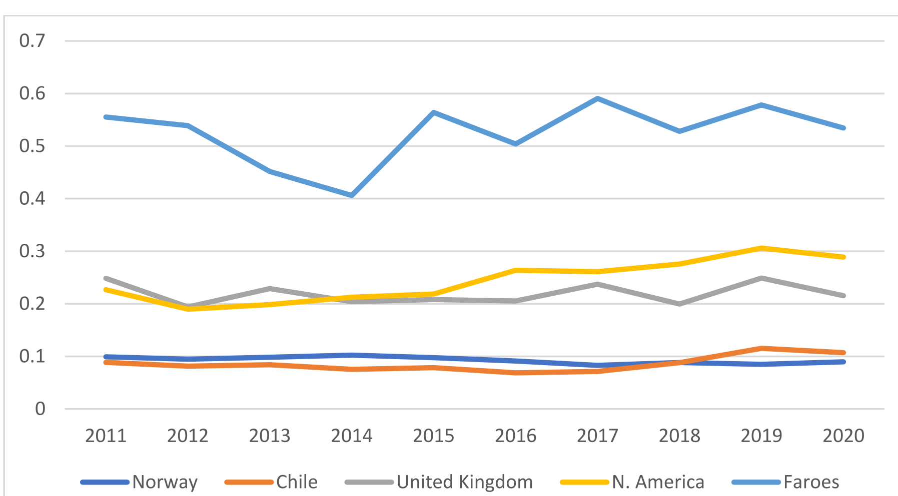

Fig. 3. HHI's for the five largest production countries of Atlantic salmon.

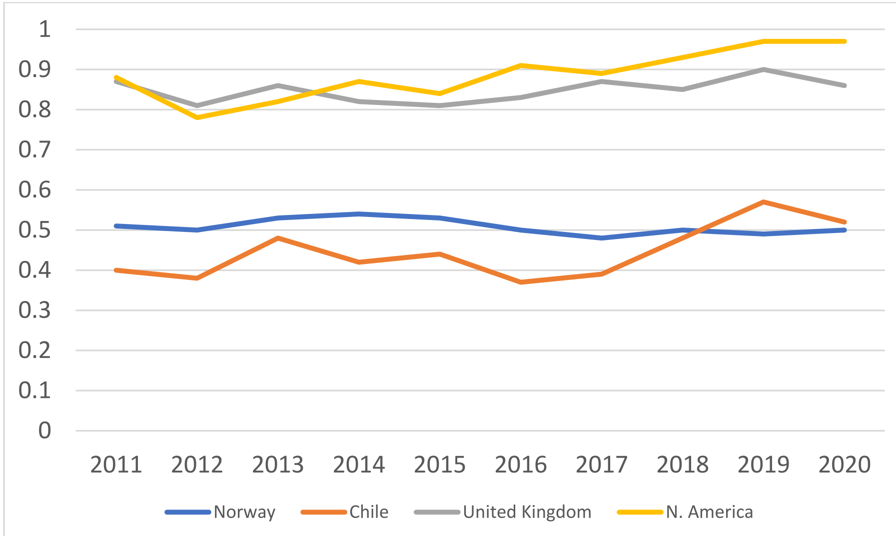

Fig. 4. CI_4's for the four largest production countries of Atlantic salmon.

5. Global concentration for all salmon

Given the evidence of a global market for salmon, one may question how informative the country specific HHIs for Atlantic salmon are. The next obvious step is to create global concentration measures. While the market integration literature indicates that all salmon competes in a global market, the focus on farmed and Atlantic salmon and the differences in data quality leads us to compute three measures: one HHI for all farmed Atlantic salmon, one for all farmed salmon and one for all salmon. These are shown in Fig. 5.

The most important conclusion is that all HHIs show a low level of concentration or what is labeled as unconcentrated markets as all HHIs are well below 0.1. Atlantic salmon is the only species that are produced by the same company in several countries, but the data in Mowi (2021) allows this to be accounted for by allowing these companies' global production to be computed. Not surprisingly, given that Atlantic salmon is the sector where the large companies are most prominent, the concentration is the largest. However, the HHI is still moderate at 0.061 in 2020. It is also noteworthy that the degree of concentration is being reduced over time as the HHI was at its highest in 2011 at 0.082. This primarily reflects the fact that the share of the production of Chile and Norway has increased and therefore that their lower concentration levels are impacting the aggregate measure. However, it is worthwhile to note that production in countries other than the top five also increased from 2011 to 2020.

The development of the HHI for all farmed salmon follows the one for Atlantic salmon closely, but at a somewhat lower level of concentration. This indicates that a significant share of the production of other farmed production is conducted by companies that does not produce significant quantities of Atlantic salmon, if at all. In both Chile and Norway there are companies that specialize in trout (and/or coho in Chile), or companies that primarily produce these species. In addition, there are countries that only produce other species than Atlantic salmon with Japan and New Zealand as examples.

Given the large number of small fishing vessels and the still relatively significant quantity being supplied from wild fisheries, it is not surprising that the HHI when also the wild salmon is accounted for is significantly lower than the two HHIs for the farmed salmon.

6. Concluding remarks

A number of the salmon aquaculture companies have grown to a significant size in recent decades. There are two main explanations for this. Concerns with respect to the competitiveness of the industry have been raised, particularly for Atlantic salmon, the largest species. The fact that more than 90% of the production originates in only five countries

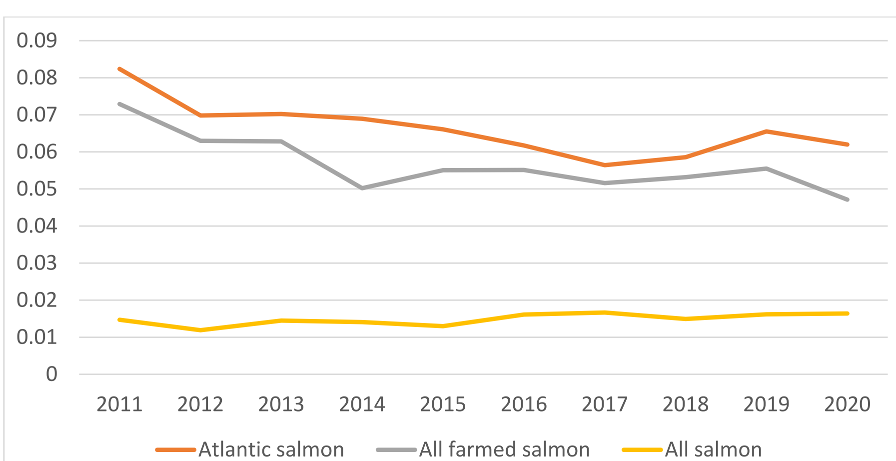

Fig. 5. HHI's for Atlantic salmon, all farmed salmon, and all salmon.

adds to this concern. However, innovations and new technology creating scale economies at the farm level as well as in processing and sales is an alternative explanation that would make larger companies a natural outcome.

In this paper, we investigate the concentration in the salmon industry with Herfindahl-Hirschman Indexes (HHIs) as the main tool. The results show that for Atlantic salmon, the degree of concentration is high in some of the smaller producer countries but that the industries in Chile and Norway are unconcentrated. However, as there is significant evidence of a global market for salmon and the largest companies are multinational, it is not obvious that the national concentration measures are very interesting. As only a few of the largest companies are multinational, and Mowi is the only company with production in all the five main producer countries, it is not too surprising that the global HHI for Atlantic salmon is lower than any of the national measures. Hence, it is clear that the salmon industry globally is unconcentrated.

The global HHI has a slightly decreasing trend, indicating that the industry globally has become less concentrated during the last decade despite the fact that the production in aggregate and for the largest companies are increasing. The slightly decreasing trend in concentration is mostly caused by the two largest producer countries, Chile and Norway, increasing their share of the production as these two countries also have the lowest concentration rates. The increased production is most likely due to a rapid demand growth (Brækkan et al., 2018) that is faster than the production growth. This has led to high prices good profitability (Sikveland et al., 2022; Zhang and Tveterås, 2022), and exploitation of marginal production sites as well as technology development like land-based farms (Bjørndal and Tusvik, 2019) and offshore farms (Osmundsen et al., 2022). However, the impact of these production technologies is, for the time being, limited. Hence, even though our data stops in 2020, it is unlikely that there will be dramatic changes in the concentration rates in the intermediate term.

When the additional farmed species and the wild salmon is accounted for the market becomes even less concentrated, and the main conclusion with respect to concentration is therefore clear. This is an unconcentrated industry with so many producers that there is no scope to exploit market power. The Chilean disease crises illustrate this well in those other suppliers made up for most of the shortfall of Chilean salmon to their main market, the U.S., and the shortfall in global production was spread globally so that prices increased everywhere (Asche et al., 2018; Salazar and Dresdner, 2021). The main cause for the increased firm size that one can observe in the industry is therefore most likely due to scale economies at the plant level, as evidenced by increased average farm size in Norway (which is the only country such data is available for), and in processing and sales, which are features that are common in most food processing industries (Morrison-Paul, 2001). The scale economies in production may be augmented by further scale economies in logistics and marketing (Asche et al., 2018).

CRediT authorship contribution statement

Rudresh Pandey: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Frank Asche:** Conceptualization, Investigation, Validation, Writing – original draft, Writing – review & editing. **Bård Misund:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization. **Rune Nygård:** Conceptualization, Validation, Investigation, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition. **Olugbenga Michael Adewumi:** Conceptualization, Validation, Investigation, Writing – review & editing. **Hans-Martin Straume:** Conceptualization, Validation, Investigation, Writing – review & editing. **Dengjun Zhang:** Conceptualization, Validation, Investigation, Writing – review & editing.

Declaration of Competing Interest

Asche and Misund has consulted for Mowi, Salmar, Lerøy, Grieg and Cermaq. The other authors declare no conflict of interests related to this article.

Data availability

Data will be made available on request.

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