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SALMON AQUACULTURE: LARGER COMPANIES AND INCREASED PRODUCTION

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□ *Salmon farming is among the most successful aquaculture industries with a production growth that is substantially higher than aggregate aquaculture production in recent decades. It is well known that innovations and productivity growth are the main sources for this development. In this article we look closer at two potentially important factors in production growth, development of farm size and company size directly through economies of scale and indirectly through capacity in R&D, innovation, sales and marketing. In Norway, production per license has increased from 26 tons in 1980 to 1,130 tons in 2010, suggesting a substantial intensification in the industry. In all five leading salmon producing countries, the degree of concentration has increased and the large firms have become bigger over time.*

Keywords aquaculture, company size, productivity, salmon

INTRODUCTION

Aquaculture has been the world's fastest growing food producing industry during recent decades (Food and Agricultural Organization [FAO], 2010). Production has increased more than 20-fold from 1970 to 2010, from 2.6 million tons to 60.4 million tons. This is largely caused by the "blue revolution," as producers gained control over the production process, thereby allowing systematic innovation and R&D and as producers applied knowledge and technology from the agricultural sector to the production of seafood species (Anderson, 2002; Asche, 2008; Smith et al., 2010a). This has led to a tremendous productivity growth that has allowed production cost to be reduced, making the aquaculture product more competitive (Asche, 2008).

Salmon is among the most successful aquaculture species when measured by production growth. With production growing from 12,000 tons

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in 1980 to over 2.4 million tons in 2011, production has increased even faster than total aquaculture production, indicating an even faster innovation rate and productivity growth than for aquaculture in general.[1] There are a number of sources for this productivity growth, including improved inputs, better production practices at the farms, improved logistics and more efficient supply chains, as well as increased scale (Asche, 2008).

A number of studies have investigated productivity growth and scale economies at the farm level, primarily in Norwegian salmon aquaculture. Less attention has been given to company size, primarily because data at this level is hard to come by. However, several companies have grown very large, and mergers and acquisitions are also a part of the growth of the salmon industry. The largest company, Marine Harvest, holds a major position in all significant salmon producing countries and produces more than 20% of all Atlantic salmon. Mergers and acquisitions seem to have taken place with different objectives. Some companies are primarily large salmon producers integrating horizontally.

Other companies also integrate vertically, and when it comes to vertical integration there is more variation in the approaches. Most companies control their harvesting plant, and many also control an export activity and/or their supply of smolts. Some companies also hold broodstock and/or conduct downstream processing activities. Cermaq is both a feed and fish producer, and Marine Harvest confirmed in 2012 that they intend to build a feed plant in Norway[2]. On the other hand, Nutreco disinvested in salmon farming in 2006 to focus on feed production through their subsidiary Skretting by selling Marine Harvest to PanFish.[3]

With the available data, it is not possible to conduct a traditional productivity analysis accounting for the firm structure. However, it is possible to shed light on the issue by using different data showing the development of firm size and dynamics. We will show how the average farm size has developed in Norway, the largest producing country with the most heterogeneous firm structure. We also have access to data showing how many companies it takes to reach 80% of production in the five leading salmon producing countries in three year intervals from 1997 (Norway, Chile, Scotland, Canada and the Faroe Islands), allowing a measure of the concentration in the production of Atlantic salmon in these countries. This provides empirical evidence with respect to whether increased farm size and company size is important for a rapidly growing aquaculture industry. The data that allows us insights in the development in concentration over time does not have enough information to allow us to construct more formal concentration measures. However, we are able to do that for 2010 by constructing Herfindal indexes using a more recent data set.

The article is organized as follows. Next, a brief overview of farmed salmon production is provided, before the literature on productivity growth is

reviewed. The development in farm size in Norway is discussed before data on the development of concentration in the five leading salmon-farming countries is provided, and concluding remarks follow.

SALMON PRODUCTION

Global farmed salmon production has increased from 12,000 tons in 1980 to over 2.4 million tons in 2011. In 1980, salmon trout was the most important species with 44.3% of the production, followed by Atlantic salmon with a 37.2% share.[4] This largely reflects the fact that trout was domesticated before salmon. However, as the industry matured, Atlantic salmon has become the dominant species with a production share of 77.9% in 2010, followed by salmon trout with 15.2% and coho with 6%.[5] This is largely due to better growth performance, and also that it is easier to have Atlantic salmon available for the market at all times of the year (Asche & Bjørndal, 2011).

Salmon is produced in significant quantities in only a handful of countries. In Figure 1, we show production by country for the five largest countries, Norway, Chile, Scotland, Canada and the Faroe Islands, as well as an aggregate category for all other countries. Norway has been the largest producer throughout the industry's history, and had a production share of 51% in 2010. Chile became the second largest producer in the 1990s and had a production share of 28% in 2010. Chile is the only country that produces significant quantities of all the main species, and the only significant producer of coho with more than 90% of the production. In Figure 1, one can also clearly see the effect of the disease problems caused by the ISA

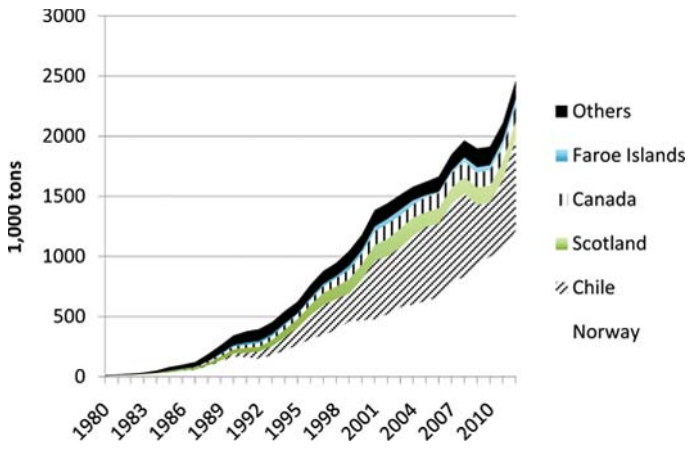

FIGURE 1 Global salmon production by country. *Source:* Kontali Analyse (personal communication, March 4, 2012) (color figure available online).

in Chile, which reduced production of Atlantic salmon from almost 400,000 tons in 2006 to 130,000 tons in 2010 (Asche et al., 2009; Hansen & Onozaka, 2011). In 2012, Chile's production share is estimated to be 31%. This means that the two leading producer countries, Norway and Chile currently make up over 80% of total production.

With production shares in parentheses, Scotland (7.4%), Canada (5.7%) and the Faroe Islands (2.7%) round out the five leading producer countries. Hence, the five leading salmon farming countries will make up 94.6% of the production in 2012. This leaves a share of only 5.4% for producers in other countries. The production share in the smaller salmon producing countries has been steadily declining, and reflects that productivity development is weaker for the producers in those countries (Asche & Bjørndal, 2011). This is also an indication that the scale of production matters. Tveteras (2002) and Tveteras and Batteese (2006) show that there are agglomeration effects in Norwegian salmon aquaculture, indicating that there are external economies of scale associated with regional clustering of salmon farming.

PRODUCTIVITY GROWTH

It is well documented that productivity growth is the main driver in the increased production of farmed salmon, as innovations that lead to productivity growth also improve the competitiveness of salmon (Asche, 2008). However, the scope for productivity growth has been limited by available technology as well as regulations. In most salmon producing countries, there are regulations that directly limit the size of a farm such as ownership and pen volume regulations in Norway, or indirectly such as restrictions on emissions as in Scotland or Denmark.[6] Regulations also restrict technology and production practices at a more detailed level such as feed ingredients (Torrissen et al., 2011) and production technology including restrictions on the use of genetically modified fish (Smith et al., 2010b).

Due to data availability, virtually all productivity studies in relation to salmon farming have been carried out on Norwegian data.[7] Salvanes (1993), Bjørndal and Salvanes (1995), Asche and Tveteras (1999), Tveteras (1999, 2000), Guttormsen (2002), Andersen, Roll and Tveterås (2008), Asche, Roll and Tveteras (2009), Nilsen (2010), Aasheim et al. (2011), Vassdal and Holst (2011) and Roll (2013) show that there has been substantial technological change over time, that this varies between years, it is technologically non-neutral and there are allocative inefficiencies and regional differences that have been reduced over time. Moreover, early on there were economies of scale that became exhausted in the early 1990s, but that reappeared after 1992 when ownership regulations that limited ownership to

majority in one farm were lifted. This will be further discussed in the next section. Asche and Bjørndal (2011) indicate a similar development with respect to productivity growth also in other salmon-producing countries, but with some important differences due to the availability of locations and regulations.

While most of the focus has been on productivity growth at the farms, we also know that other sources are important. Tveteras and Heshmati (2002) shows that about two thirds of the productivity growth is due to improved input factors, and Asche (2008) discusses how this is due to an increasing variety of specialized input suppliers. Feed is the most important input factor with a cost share of over 50%, and the feed producers are among the most important sources for productivity growth (Torrissen et al., 2011) and quality enhancement (Forsberg & Guttormsen 2006a, 2006b). Guttormsen (2002) shows that in the short run, feed can be regarded as the only variable factor, and that it contributes significantly to productivity growth despite being an increasing cost share due to better quality and lower price.

Higher prices on key ingredients like fish meal (Asche, Oglend, & Tveteras, 2013) are largely overcome by improved input mixes using new ingredients (Tacon & Metian, 2008; Tveteras & Tveteras, 2010; Torrissen et al., 2011). Also downstream innovations like improved logistics and transportation systems are important (Asche, Roll, & Tveteras, 2007), as well as more sophisticated customer relationships (Kvaløy, 2006; Kvaløy & Tveteras, 2008; Olson & Criddle, 2008; Larsen & Asche, 2011).[8]

Several of these innovations, for instance contract sales, are possible only because the companies have become larger (Kvaløy & Tveteras, 2008). Improved logistics have also helped fuel product development and demand growth (Asche et al., 2011) and marketing (Kinnucan & Myrland, 2002, 2005, 2007). It is also of interest to note that wild salmon producers have been able to segment wild from farmed salmon (Davidson et al., 2012; Fernandez-Polanco & Luna, 2012; Roheim, Sudhakaran, & Durham 2012), even though the price determination process is common (Asche et al., 2005; Tveteras & Asche, 2008).

SCALE IN NORWAY

As one can see from Figure 1, there has been a tremendous increase in salmon production in Norway. The production in 1980 was 7,800 tons, while it is expected to be at 1.2 million tons in 2012. This has been possible primarily due to increased intensification as production per license has increased, although new licenses have also been awarded.

To operate a salmon farm in Norway one needs a license, and with one license one can produce either Atlantic salmon or salmon trout. A license

specifies where one can operate while also providing a measure that limits production. Within a region one can apply to the Directorate of Fisheries to move the license to a new location, and one can also operate several licenses together at the same site. Until 2002, the production limitations were some form of limit on pen size, while since 2004 there is a Maximum Allowable Biomass (MTB) for each license. Until 1992, regional policy concerns dictated that one could have a majority share in only one farm, basically creating an owner-operated industry.[9]

With this restriction, the largest salmon farming companies were located outside of Norway in the early days of the industry. From early on, Marine Harvest (originally a Scottish company) was the largest company, and also many Chilean companies are thought to have been larger (Asche & Bjørndal, 2011). The ownership constraint in Norway was removed in 1992, and a process of company growth by mergers and acquisitions commenced. The larger companies also got access to new types of suppliers, including the capital market. In 1997, the first company, PanFish, was listed on the Norwegian stock exchange.

Studies using data until the mid 1990s generally found that economies of scale had been exploited and that the industry in the early 1990s could be characterized by constant returns to scale (Salvanes, 1993; Guttormsen, 2002). The removal of the ownership restrictions enabled firms to start operating more than one license at one location. From the late 1990s, companies started to operate several licenses at a single farm; some farms operate up to five licenses at a single location when there is sufficient environmental carrying capacity. This has also led to a significant increase in the size of the pens.

In Figure 2, we show a schematic intersection for typical pen sold in Norway in 1980 and 2010.[10] The pen from 1980 has a diameter of 5 meters

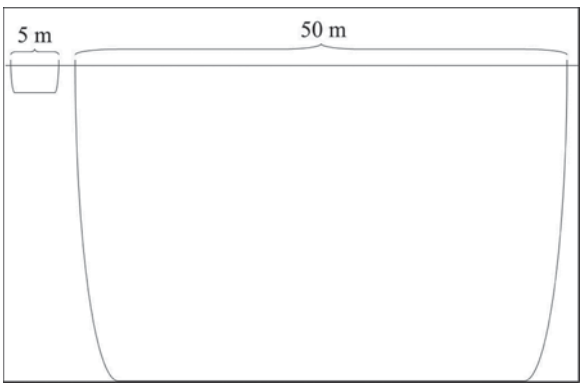

FIGURE 2 Intersection of pen from 1980 and 2010.

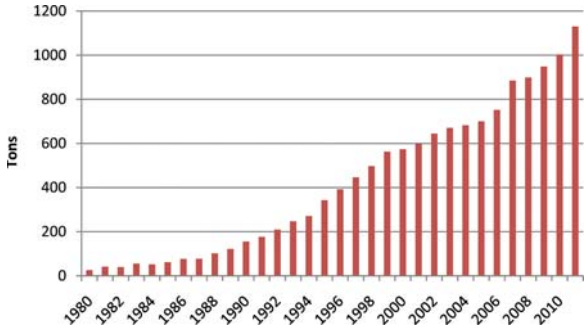

FIGURE 3 Average production per license in Norway. *Sources*: Norwegian Directorate of Fisheries (2007) and Statistics Norway (2013) (color figure available online).

and is 4 meters deep. The pen from 2010 has a diameter of 50 meters and is 45 meters deep. As one can see, the pen from 2010 is several magnitudes larger than the pen from 1980. The size of the pens continues to increase, as pens are now available with a diameter of up to 70 meters. This development has lead more recent studies to report increasing returns to scale (Asche, Roll, & Tveteras, 2009; Nilsen, 2010), and accordingly, there still seems to be economic reasons for further growth in plant size. However, the potential for further cost reductions due to scale economies seems to be relatively marginal and larger farm sizes due to economies of scale at the farm level does not seem to be the driving factor for the large multi-farm companies.

To the extent that there are limitations on farm size these seem to primarily be environmental, although there are also technical challenges in building large pens that are able to withstand rough weather and storms. Moreover, larger pens also raise risk concerns with respect to the impact of any specific event, as the economic and environmental consequences can be much larger. For instance, if there is an accident that leads to salmon escaping the pen, there are many more fish to escape in a larger pen. Larger pens and farms are also a concern with respect to the interaction between wild and farmed salmon, and in particular as hosts for sea lice (Torrissen et al., 2013).

In Figure 3, the average production per license in Norway is shown. As one can see, this has increased dramatically from 26 tons in 1980 to 1130 tons in 2010. This is more than a 43-fold increase. Hence, the production has intensified dramatically over the last 30 years. Although this is partly due to larger pens, it is also influenced by a number of other factors. Among them are fish health innovations like vaccines, as well as faster growth due to breeding programs, and improved feed that has halved production time (Asche & Bjørndal, 2011).

Similar data is not available for other salmon producing countries.[11] Early on there is no doubt that the largest Scottish companies and farms were larger than their Norwegian counterparts, but as Scottish production stagnated after 2003, regulations have largely prevented further growth. In the 1990s, the largest farms in Chile were also larger than the Norwegian farms, but industry sources indicate that this is no longer the case.

NUMBER OF COMPANIES

So far we have seen that the development of the salmon industry has several features where it seems to be an advantage to be a large company. However, the data presented so far does not give clear evidence that companies must be larger than a single plant to exploit the scale advantages in production. There are some indications that in more sophisticated supply chains there can be economies of scale, scope and coordination (Kvaløy & Tveteras, 2008; Olson and Criddle, 2008; Larsen & Asche, 2011). Still, these advantages that often occur downstream do not necessitate big production companies. For instance, while pork production in the United States is an example of an industry with increased vertical integration, poultry production provides an example where owner-operated farms contracting to large processors is the most common organization (Olson & Criddle, 2008).

To a large extent, the evidence with respect to whether company size is beneficial in any specific industry will then have to be provided by the actual numbers. We have access to data on the number of companies in each of the five leading salmon producing countries that make up 80% of the production for every third year from 1997 from Kontali Analyse and Nordea Bank. Unfortunately, the data set does not contain any information on the specific companies and their production, and further analysis with respect to concentration is not possible with these data. For readability, we present the data by country.

Norway

As noted before, Norway is clearly the largest producer of salmon, and since ownership regulations were lifted in 1992, a strong consolidation process has taken place. In 1991, there were 823 licenses, and as the industry with few exceptions was an owner-operated industry, the number of independent companies was of a similar magnitude. By 2000 the number of companies was reduced to 296, and in 2010 it was 171.[12]

In Figure 4, the number of companies making up 80% of the salmon production in Norway is shown together with total production. For 2012,

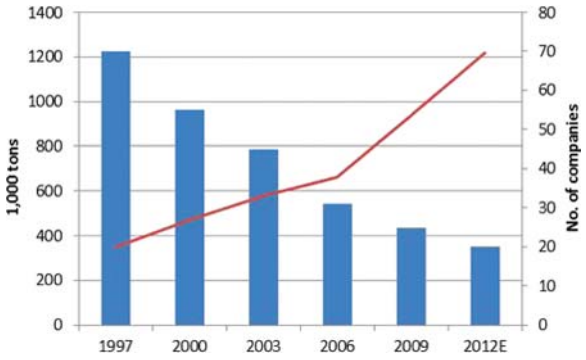

FIGURE 4 Norwegian salmon production and no. of companies making up 80% of production (no. of companies are measured by the vertical bars). *Sources:* Kontali Analyse (personal communication, March 4, 2012) and Nordea Bank (personal communication, February 12, 2012) (color figure available online).

the number of companies is estimated based on provisional number as of August 2012. This is indicated in this and later figures by adding an E to the years where the number of companies is estimated. The figure shows that the number of companies necessary to reach the threshold of 80% is declining rapidly, indicating a substantial increase in the size of the largest companies. In 1997, 70 companies made up 80% of the total production. This decreased to 25 in 2009 and it is estimated to be 20 in 2012.

The rapid consolidation process has also raised some concerns, and in 2005 a new set of regulations was implemented that limited the number of licenses that a single company could own to 15% of the total number of licenses without any notice, but where one could apply to the minister of fisheries to increase this to 25%. The last measure was primarily implemented to accommodate Marine Harvest, which already owned 25% of the licenses in Norway and it is the only company for which this exception has been granted. In 2013 the ownership limit was extended to 40%

Chile

Since the mid 1990s, Chile has been the second largest salmon producing country, although the disease crisis briefly made Scotland the second largest producer of Atlantic salmon in 2010. The number of companies making up 80% of the salmon production is shown together with total production in Figure 5. Also in Chile there is a general tendency towards fewer but larger companies, from 35 in 1997 to 10 in 2006, but increasing to 18 in 2009 and an estimated 12 in 2012. Additionally, the disease crisis had an impact on the number of companies required to produce 80% of the total quantity. This is also an indication that the larger companies were more focused on producing Atlantic salmon than the industry at large, and

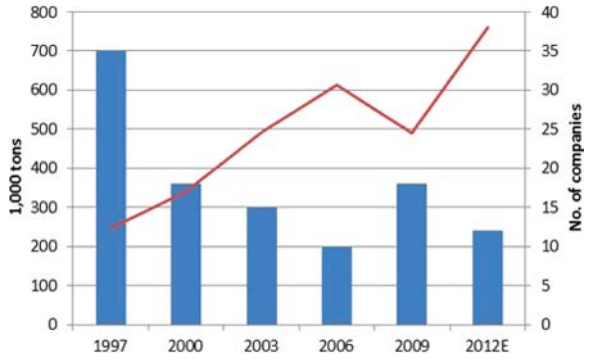

FIGURE 5 Chilean salmon production and no. of companies making up 80% of production (no. of companies are measured by the vertical bars). *Sources:* Kontali Analyse (personal communication, March 4, 2012) and Nordea Bank (personal communication, February 12, 2012) (color figure available online).

possibly that they were harder hit by the disease crisis.[13] Given that more than 80% of the production in 2006 was made up of only 10 companies, one can also expect that the largest companies will increase their share of the production further when the industry recovers.

Scotland

In Figure 6, Scottish production is shown together with the number of companies that makes up 80% of total production. The number of companies was 12 in 1997, declined steadily to 5 in 2009 and is expected to be 4 in 2012. This process has occurred despite the fact that Scottish salmon production peaked in 2003. Hence, there are apparently factors beyond increased production that are driving consolidation in the industry. The

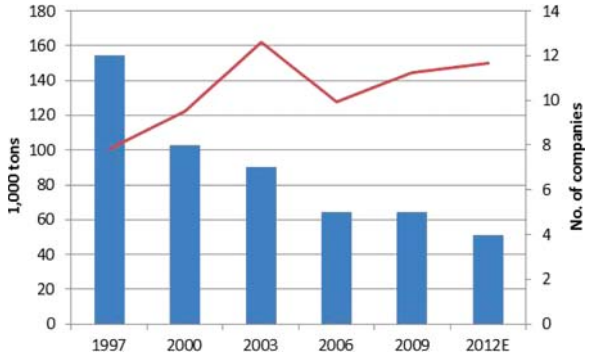

FIGURE 6 Scottish salmon production and no. of companies making up 80% of production (no. of companies are measured by the vertical bars). *Sources:* Kontali Analyse (personal communication, March 4, 2012) and Nordea Bank (personal communication, February 12, 2012) (color figure available online).

absence of growth largely seems to be caused by tight regulatory conditions, as the industry struggles to get access to new locations. As such, the Scottish industry seems to be an example what Chu et al. (2010) describe as an industry where regulatory conditions are more important than market opportunities and technology development for industry performance, and thereby preventing growth and limiting further development.

Canada

In Figure 7, Canadian production is shown together with the number of companies that make up 80% of total production. The number of companies was 12 in 1997, and declined steadily to 5 in 2009 and is expected to be 4 in 2012. Also in Canada, production has flattened out, and again, regulatory issues that prevent new locations are the main reason. Moreover, the consolidation also continued here even when production growth disappeared.

Faroe Islands

In Figure 8, Faroese production is shown together with the number of companies that make up 80% of total production. The number of companies was 30 in 1997. A wave of mergers and acquisitions led the number of companies to rapidly reduce to 8 in 2003, before the process continued at a steadier pace to 3 in 2009, which is also the expected number in 2012. Along with Chile, the Faroe Islands have been substantially affected by the ISA disease, with production declining for several years after peaking

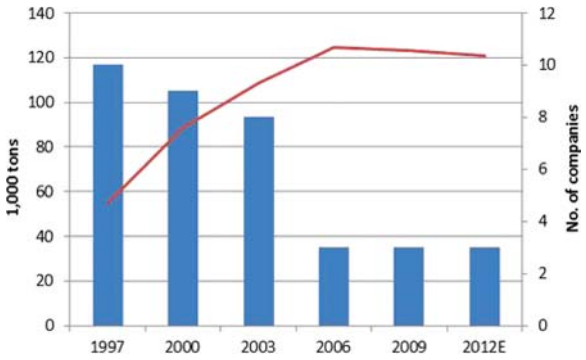

FIGURE 7 Canadian salmon production and no. of companies making up 80% of production (number of companies are measured by the vertical bars). *Sources:* Kontali Analyse (personal communication, March 4, 2012) and Nordea Bank (personal communication, February 12, 2012) (color figure available online).

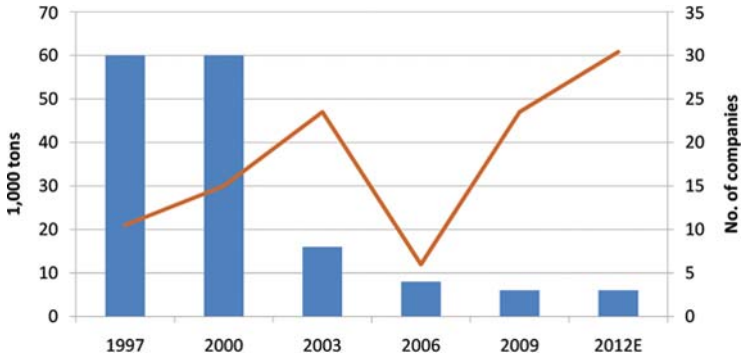

FIGURE 8 Faroe Island salmon production and no. of companies making up 80% of production (number of companies are measured by the vertical bars). *Sources:* Kontali Analyse (personal communication, March 4, 2012) and Nordea Bank (personal communication, February 12, 2012) (color figure available online).

in 2003. Most of the consolidation took place in the growth phase until 2003, but has also continued afterwards. In contrast to Chile, the larger firms do not seem to be disproportionally hit by the disease problems.

Multinationals

Some of the larger companies are also multinational, making the global salmon production relatively concentrated. We do not have access to similar numbers as for each of the countries above for the industry on a global scale, but Nilsen and Grindheim (2011) allow us to provide a snapshot for Atlantic salmon in 2010, and with more detail. Marine Harvest is clearly the largest company with more than 20% of the global production of Atlantic salmon in 2010 (Nilsen & Grindheim, 2011), and is also the only company that operates in all of the five largest salmon producing countries. By comparison, the second largest company, Lerøy, only farms salmon in Norway and produced 8.9% of all Atlantic salmon in 2010.[14]

On the top 10 list of Nilsen and Grindheim (2011) for Atlantic salmon in 2010, only four companies have international farming operations (but these firms are all on the top six lists), and the final two among the top six (Lerøy & Salmar), have joint ownership of the Scottish company Norskott. Smaller companies are mostly located in a single country. Hence, despite the multinational companies, global salmon production seems to be less concentrated than what is the case for each individual country. According to the numbers provided by Nilsen and Grindheim (2011), the top 10 producers in 2010 made up 64% of global production.

The data provided by Nilsen and Grindheim (2011) also allow us to create a Herfindal-Hirschman Index (HHI) for each of the five countries as well as globally. The HHI is a commonly used market concentration

measure in anti-trust cases. According to U.S. merger guidelines, a HHI below 0.15 is an unconcentrated market, a HHI between 0.15 and 0.25 is a moderately concentrated market and a HHI larger than 0.25 indicates a high concentration. Let S_i be the market share of company i. The HHI in a market is than given as $HHI = \Sigma S_i^2$ for the 50 largest (or all) firms in a market. The index is range from 0 to 1, and is 1 for a monopolistic industry. The squared market share implies that the index is proportional to the market share weighted by market share.

Hence, the index will have a higher value in a market with one large and one small firm than in a market with two firms of the same size. A challenge in our case is that we never observe data for all firms, and we will therefore have to make assumptions with respect to the market share of the unobserved companies. We try to be conservative, so that we assign the share of the production globally and in each country to relatively few companies, so that our estimate will be an overestimate.

The results are as follows: Globally, the 30 companies we have data for make up 90.8% of the production. Assuming the remainder of the production is attributed to companies equally large to the smallest of the 30 observed companies, the global HHI becomes 0.079. For Norway, we have data on 12 companies making up 70.6% of the Norwegian production. We assume that the next 10 companies are equal in size to the last observed, then continue with companies of two assumed smaller sizes (two thirds and one half of the smallest observed company) and get a HHI of 0.091. For Chile we have data on 15 companies and find a HHI of 0.087, for Canada we observe 4 companies and find a HHI of 0.221, for Scotland we observe 5 companies and find a HHI of 0.197 and for the Faroe Islands we observe the three existing companies and find a HHI of 0.530.[15]

These results indicate that globally, salmon production is not very concentrated despite the size of the largest company, Marine Harvest. Moreover, in the two largest production countries, Norway and Chile, the concentration level is also very moderate. The concentration level is higher but still moderate in Canada and Scotland, and high in the Faroe Islands. It is interesting to note how the concentration level increases for the producer countries with lower production levels. However, given the global nature of the salmon market, there is no reason to expect that this concentration gives those producer countries with lower levels of production any opportunity to influence prices. Rather, given that the observed companies make up more than 75% of total production, the concentration in the smaller producer countries seems to be an indication that a relatively large company size is beneficial when targeting the main markets for salmon.

Finally we would like to note that we do not have data to account for the farmers of coho and salmon trout. However, these are often smaller firms,

therefore, the degree of concentration is likely to be less if these companies are also accounted for.

DISCUSSION AND CONCLUSIONS

Salmon farming is among the most successful aquaculture industries in terms of quantity produced. It is well known that innovation leading to productivity growth is the most important factor in explaining this growth (Asche, 2008). It is also well know that in periods there have been economies of scale in the industry (Guttormsen, 2002), as the biological production process makes it difficult for production to keep pace with technological development. This has also led to periods with technical and allocative inefficiencies, as companies and regions have tried to catch up with the best practices (Nilsen, 2010; Roll, 2013). In this article we provide more evidence with respect to the growth in the size of each farm in Norway, as well as of the increased size of the salmon farming companies in all the leading salmon-producing countries.

Technology has increased the average size of each salmon farm tremendously, although better feed and faster growing fish also contribute to increased production at each farm. Although exact data is available only for Norway, a similar development has taken place in all the salmon producing countries. As such, it seems clear that farm size has been important for the production growth in the industry. The stagnation of the industries in Canada and Scotland can also to some extent be attributed to regulations that prevent access to new locations, and therefore also limit the extent to which the industry in these countries can adopt the latest technology when this also requires new sites that allow bigger farms. It is also interesting to note that in Chile it seems like the smaller companies dealt better with the ISA crisis; however, this was not the case in the Faroe Islands.

The salmon farming industry is very heterogeneous when it comes to company size. There are still a number of companies operating a single farm, while there is also an increased degree of concentration in all the leading producer countries. Hence, while it is not clear from farm level production data that companies must become bigger to foster productivity growth, the fact that the industry does become more concentrated in all large producing countries suggests that there are scale benefits in other parts of the value chain. Increasing company size is certainly true in the countries where production is increasing, as the larger companies take a disproportionate share of the growth when the industry is becoming more concentrated in the same phase. As such, it seems to be advantageous to be big in the purchases of services, the production and/or in marketing and sales, and that the existence of big companies has helped the salmon industry grow. However, there also seem to be other advantages, as the industry is

becoming more concentrated also in countries with stagnant production. This suggests that there may also be economies of scale in complying with regulations and dealing with red tape.

Although this study indicates that larger companies have advantages, it should also be noted that the concentration level in the salmon industry context as measured by a Herfindal-Hirchman Index is low for the industry globally. The levels are also low in the two largest producer countries, Norway and Chile, higher but still moderate in Canada and Scotland, and high only at the Faroe Islands, the smallest producer country. As there is a global market for salmon, there is accordingly no reason for concerns with respect to the competitiveness of the industry.

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NOTES

1. Of course, some of the production growth is also due to new production sites (Asche, 2008). However, new sites are likely to be less important for salmon due to regulatory measures such as moratorium in new licenses for longer periods in Canada and few new licenses awarded in most of the other large salmon producing countries (Asche & Bjørndal, 2011).
2. http://hugin.info/209/R/1652625/533535.pdf (p. 26).
3. PanFish continued by taking the name Marine Harvest for the merged company (Asche & Bjørndal, 2011).
4. Salmon trout (Onchorynchus mykiss) is large rainbow trout and are also known as steelhead.
5. The markets for the different salmon species are well integrated (Asche & Guttormsen, 2001; Asche et al., 2005), in contrast to what is the relationship with other species (Asche, Gordon, & Hannesson, 2002, Nielsen, Smit, & Guillen, 2009). The common price development also provides the species with a similar degree of competitiveness (Tveteras et al., 2012). However, it is also of interest to note that there does not appear to be a central market, a feature that can be observed for many agricultural commodities (Asche, Gjølberg, & Guttormsen, 2012).
6. See Nielsen (2012) for an interesting discussion of the effects of regulations on emissions in Danish trout aquaculture.
7. However, there are of course a number of studies for other species. Sharma and Leung (2003) provides a review and Shamshak and Anderson (2009), Shamshak (2011) and Gillespie, Nyaupane, and Boucher (2012) provide some recent examples.
8. Larger companies that can coordinate harvesting activities can also avoid some of the issues related to seasonality in growth as discussed by Guttormsen (2008), and also reduce risk due to environmental shock due to the diversification implied by different locations (Oglend & Tveteras, 2009; Torrissen et al., 2013).
9. There were a few exceptions as some companies operated more than one farm when the first set of regulations was implemented in 1973.
10. This information is provided by Knut Molaug, who was CEO of a leading equipment supplier (AKVA) until 2011.

11. Olson and Criddle (2009) provide an indication of firm size in Chile using export data by company.
12. After 1991 the number of licenses has increased to 991 in 2010, having been awarded in three openings (in 1995 only for the two most northern counties, and in 2002 and 2008).
13. Note that if Asche et al. (2009) is correct in assessing that the disease crisis really started in 2005, the crisis goes a long way to explain the increased production per license in Norway in 2007 (Figure 3), and the productivity slowdown noted by Vassdal and Holst (2011). It is also the most likely cause for the improved conditions for Alaska salmon fishermen (Williams, Herrmann, & Criddle, 2009; Valderrama & Anderson, 2010).
14. Lerøy and Salmar jointly own the Scottish firm Norskott, but this operation is treated as a separate firm in the data.
15. It should be noted that the HHI for Chile is computed for a very untypical year as production was very low in 2010 due to disease problems (Asche et al., 2009). However, the main insight, a relatively low concentration level is not likely to change if data for other years were available.

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