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Deliverable 1.5

Methods for evaluating competitiveness in seafood sectors

February 4th, 2019

Executive Summary

This deliverable consists of two parts, a general description of methods used to assess competitiveness in seafood sectors as well as economic activity in general and a paper on competitiveness in salmon farming in Norway, Chile, Scotland, the Faroe Islands and Canada that has been submitted to an academic journal. The intended audience of the deliverable is primarily the scientific community, but the executive summary is written in plain language and is therefore understandable to other stakeholder groups.

Two strongly linked concepts – comparative advantage and competitiveness - have for a long time been a topic of interest for authorities and economic actors. Firms are of course concerned with survival and profitability, but also nations are concerned with competitiveness; developed countries want to maintain strong positions while developing countries seek to improve theirs.

Due to not being well defined in economic literature, several definitions and methods to measure competitiveness have been used. These fall into two general categories. Neoclassical economists focus on trade success and the use of real exchange rates, comparative advantage indexes and export indexes. Strategic management proponents advocate the importance of firm structure and strategy and measure competitiveness using cost indicators, productivity and efficiency. Siggel (2006) discusses four dimensions of competitiveness where indicators differ; macro vs. micro-economic, dimensionality, comparison basis, static or dynamic, deterministic or stochastic and positive or normative.

The macroeconomic concepts used for measuring competitiveness mainly fall into four categories: real exchange rate and real effective exchange rate; productivity; business climate indices; and export market share, net export index and other trade indices. The microeconomic concepts mainly applied can be classified into four categories: studies based on revealed comparative advantage and relative export advantage; domestic resource cost; cost of production; profitability measures.

A literature search, employing Google Scholar, was carried out, yielding a total of 43 papers that dealt with competitiveness in the aquaculture and seafood sector. Of these, 32 papers employed the trade-driven measures developed around the "revealed comparative advantage" concept, whereof 19 employed relative comparative advantage (RCA), eight applied the concept of relative trade advantage (RTA) and five used relative export advantage (RXA). The trade-driven concept of constant market share (CMS) was used in 10 studies, eight papers were based on comparison of domestic resource costs (DRC), and two studies each focused on export competitiveness (XCI) and full unit cost (FUC).

Studies have also been undertaken using the framework of Buckley et al. (1992), the Porter diamond and flexibility theory (Porter, 1990), data envelopment analysis (DEA), and relative unit costs (RULC) and relative producer prices (RELPR). Most of the identified studies look at aquaculture (20), mainly shrimp, while 12 studies examine seafood in general and 11 specific fish species, mostly tuna. The industry level also varies strongly between studies – from studies investigating the whole aggregated seafood sector of a country to individual farms being the subject. Several of the studies employ more than one measure of competitiveness. However, most of these use strongly linked methodologies – such as both calculating the relative comparative advantage and the relative trade advantage. Only one study was found to employ methods that are widely different. The geographic area under scrutiny also varies strongly. Most studies cover a range of countries, especially several or all EU countries, Asian or countries from the whole world.

Compared to economically larger sectors, the number of published papers is relatively small within the seafood sector. There are relatively small overlaps between the studies. Few have looked at similar products from the same countries in the same markets with methods that differ considerably. Hence, we do not consider the material to allow for comparisons or other analyses that could yield interesting and useful results and be thought-provoking for a journal to publish.

The second part of this deliverable consists of the paper *Production cost and competitiveness in major salmon farming countries 2003-2015* which was submitted to the journal Aquaculture in January 2019. This paper investigates competitiveness in aquaculture of Atlantic salmon between the five main producer countries, Norway, Chile, Canada, Scotland and the Faroe Islands. A unique data set on production cost was used to analyse the development in the period 2003 to 2015, and hence associates production cost with production growth and market share. Costs have developed differently between countries. The two countries that stand out with strong and opposite trends in costs are Chile and the Faroe Islands. Chile sees a strong increase in cost and moves from being the least to the highest cost producer. The Faroe Islands has the opposite development and moves from being the highest to lowest cost producer. For Norway, Canada and Scotland, the changes are considerably less. With oscillations between years, absolute cost in 2015 is quite comparable to 2003 for all three countries. The level varies, with Norway having the lowest of the three, Canada a bit higher and Scotland the highest. For the Faroe Islands and Chile, major disease outbreaks dwarf any underlying trend. Differences are also related to scale, natural conditions, currency development and regulations. Results show that Norway´s position as the leading salmon producing country in terms of market share seems justified by the country's low production cost.

The paper is jointly written by two members of the PrimeFish consortium and two outsiders.

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Part 1 Methods for evaluating competitiveness in seafood sectors

Introduction

Two strongly linked concepts – comparative advantage and competitiveness - have for a long time been a topic of interest for authorities and economic actors. Firms are of course concerned with survival and profitability, but also nations are concerned with competitiveness; developed countries want to maintain strong positions while developing countries seek to improve theirs. An important question in economics is how a society's resources should be allocated. For many, high and sustained social welfare is the goal that should be attained. In determining this, the concepts are often used as a basis for analysis. These studies have a long history, dating back to at least the 17th century and initially investigated from a macro perspective, looking at the competitiveness of nations, in famous studies such as Mun (1623) and Smith (1776). Here, the trade balances between nations and production costs were used as indicators. The concept of comparative advantage was introduced by Ricardo (1817), stating that countries could benefit from trade even if their production costs were higher when the opportunity cost is less than for competitors. Which goods to produce and which to import would thus be determined by the relative advantage. Looking into the determinants of comparative advantage, Heckscher (1919) and Ohlin (1933) put forward the importance of relative endowments of input factors such as labour, capital or others.

Later, attention turned towards microeconomics and competitiveness between firms. The importance of innovation and need for constant adjustments was proposed by Schumpeter (1911). Competition among firms was discussed by Clark (1940), stressing the need for effective competition in order to develop innovations and technological progress, allowing for competitive advantage. The potential advantages that could be achieved through marketing was investigated by Alderson (1957, 1965).

Institutional economists such as List (1841), Weber (1920) and Buchanan and Tullock (1962) have highlighted the role of institutions. Public authorities, laws and regulations, trade unions, ownership structures and codes of conduct among others play an important role in determining competitiveness.

Despite all this activity, competitiveness does not have a definition in economic theory (e.g. Sharples 1990 and Ahearn et al 1990) and is a broad concept where there is no general agreed definition. Among many economists, the concept is highly controversial) and by some considered "meaningless when applied to national economies" (Mulatu 2016). This position is criticised for disregarding inefficiencies in trade stemming from market failures and comparative advantage not necessarily being exogenous.

Another school argues that proper definition of competitiveness is meaningful and has been important in the development of advanced economies (Reinert 1995). In general, competitiveness is the ability to sell goods and generate profits that ensure long-term sustainability. In line with this school, the OECD defines competitiveness as the ability of companies, industries, regions and nations to sustainably generate relatively high factor income and factor employment. Studies often adopt their own definition and choose among several specific measurement methods.

Measuring competitiveness

According to Siggel (2006) the concepts of comparative advantage and competitiveness are strongly linked but differ in a crucial aspect. He claims that as prices can be distorted or markets not in equilibrium, cost comparisons based on market prices are not always sources of comparative advantage. When prices are distorted, such comparisons will yield cost competitiveness. In order to measure comparative advantage, equilibrium and non-distorted prices must be employed.

Due to not being well defined in economic literature, several definitions and methods to measure competitiveness have been used. These fall into two general categories. Neoclassical economists focus on trade success and use real exchange rates, comparative advantage indexes and export indexes. Strategic management proponents advocate the importance of firm structure and strategy and measure competitiveness using cost indicators, productivity and efficiency. Siggel (2006) discusses four dimensions of competitiveness where indicators differ; macro vs. micro-economic, dimensionality, comparison basis, static or dynamic, deterministic or stochastic and positive or normative.

Firm or industry measures have, according to Siggel (2006), a stronger theoretical basis than indicators that focus on aggregated economies. Despite receiving strong attention in the literature, the macro indicators are still controversial. When measuring competitiveness between nations, trade measures are useful, and defined by comparative advantage according to Ricardo and Heckscher and Ohlin. Trade flows are the result of production costs and countries will specialize in the goods where they have competitive advantage.

Microeconomic indicators are plentiful, and their theoretical advantage lies in focusing on specific characteristics of firms that compete for market shares and profits. Their success can be measured through e.g. the size or change in market share or price ratios.

Indicators vary in terms of the number of dimensions that are included. Some employ only one, such as real labour cost, others include two or more dimensions such as requiring real income as a measure of welfare to be rising or constant for increasing exports to be viewed as an indicator of increased competitiveness (Hatsopoulos et al. 1988)

Evaluating competitiveness implies comparisons between entities. This can be individual producers or industries in different countries.

Measurement of competitiveness is a static concept. This hinders its usefulness in predicting changes in trade patterns that can arise from changes in comparative advantages. Changes in market share, however, can be viewed as a dynamic indicator of competitiveness.

Basing themselves on observed prices, market shares, etc, reflecting actual performance most indicators are deterministic. Some indicators are based on other variables determining competitiveness through stochastic models.

Normative competitiveness concepts involve value judgements, whereas positive ones are based on observations.

Before presenting a few different methods that have been employed in the literature, we here introduce the method suggested by Siggel (2006) as it presents the concept well and provides an informative link between comparative advantage and competitiveness.

A true measure of comparative advantage is the domestic resource cost (DRC) (Bruno 1965). This has been employed in several studies. Generalizing from two to several products, Dornbusch et al (1977) showed that an industry has comparative advantage if labour costs are less than those of the same industry in a different country. The comparative advantage of different products may be evaluated through comparing industries relative productivities with the relative wage.

Extending this further to including other inputs by extension of logic, the country or industry where the sum of costs, measured at shadow prices, have a comparative advantage. Substituting input cost with domestic value added at free-trade price, the comparison is made against the rest of the world and yielding the DRC criterion, where a is labour productivity, w_s wage rate and VA_w is value added at free trade prices.

$$a \cdot w_s / VA_w < 1$$

Intermediate inputs can be a source of comparative advantage, although tradable inputs should be available at the same price for all. Resource abundance and transport costs can result in different domestic and international prices. The same applies to non-tradable inputs. Different imperfections in domestic markets, such as protection, can result in further price distortions for inputs. An unbiased measure of comparative advantage would thus require comparison of total domestic cost to price of output, all measured at shadow prices and corrected for misaligned exchange rates. Here, unit cost ratio is the total costs divided by value of output is less than one for comparative advantage to be present.

$$UC_s = TC_s/VO_s < 1$$

Extending from this comparative advantage criterion to competitiveness requires only small adjustments according to Siggel (2006). And that is to replace the shadow prices with market ones. These can include several distortions. The unit cost ratio now becomes a measure of profitability, but unlike profit margin, it includes the opportunity cost of capital. This evaluates the domestic competitiveness. Export competitiveness is obtained by replacing the value of output with free-trade prices.

$$UC_d = TC_d/VO_d < 1$$

Methods for measuring competitiveness

As previously mentioned, several methods have been developed and employed in the pursuit of competitiveness. Siggel (2006) provides an extensive list of indicators. Here, we introduce a selection of them categorized by macro or micro perspective and sum up the remaining in a later table. The method names and the general term "competitiveness" are used as keywords along with the keywords "seafood", "fisheries" and "aquaculture" to identify studies of competitiveness in the seafood sector.

Macroeconomic perspective

Real exchange rate and real effective exchange rate

The macroeconomic applications of competitiveness are the most controversial ones. The first example of such a measure is the real exchange rate (RER). When the demand for a currency increases, such as in a competitive country, the exchange rate is strengthened (Brinkman 1987). This is utilized in the RER that is defined as the ratio between the price indexes of tradable and non-tradable commodities (Lipschitz and McDonald 1991). An improvement is using purchasing-power parities (Ball *et al.* 2006). Using this measure in an agricultural setting, Bureau and Bultault (1992) define PPP as the rate a national currency must be converted to purchase the same product in two countries.

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$\mathrm{RER} = \frac{p^T}{p^{NT}}$, where p^T and p^T are price indices of respectively the tradable and non-tradable commodities.

Productivity

Capturing macroeconomic competitiveness as an aggregate of microeconomics has also been attempted. If a country has many companies that are successful in the export market, this is a clear indication of competitiveness. Productivity is often associated with competitiveness, but this link is rarely made in studies of productivity. Productivity can be defined as the sum of all inputs used divided by the sum of output, yielding the total factor productivity. Sometimes partial productivity measures are estimated instead, using only one input. Productivity, both labour and total factor, has been suggested by Dollar and Wolf (1993). Hatsopolos et al. (1988) and Markusen (1992) have proposed closely related indicators.

Business climate indices

The "World Competitiveness Index" published annually by the World Economic Forum since 1995 is probably the most detailed competitiveness index currently in use. The latest version of the index, GCI 4.0, contains 98 indicators which are organised into 12 pillars (Schwab, 2018). The pillars are: Institutions; Infrastructure; ICT adoption; Macroeconomic stability; Health; Skills; Product market; Labour market; Financial system; Market size; Business dynamism; and Innovation capability. The computation of the index is based on successive aggregations of scores, from the most disaggregated level (indicator) to the overall GCI score. At each aggregation level, each aggregated measure is calculated by taking the arithmetic mean of the scores of its components. The overall GCI score is calculated as the average of the 12 pillars. Although the index serves a useful purpose for investors and policy makers, (Siggel (2006) has noted that its theoretical base and its aggregation method are problematic. To overcome this, Ju and Sohn (2014) have suggested using a structural equation model that reflects the structural relationships among the various factors underpinning the index. The model is then used to derive a new national competitiveness index that reflects these interrelationships.

Export market share, net export index and other trade indices

A simple measure of competitiveness is simply the export market shares using value or quantity. Calculating the ratio between net exports and the total trade results in the net export index (Banterle and Carraresi 2007). This can be evaluated both on macro- and microeconomic level, the latter when restricting the analysis to sector trade. One example is the net export index (NEI), that is defined as follows, with X being exports, M imports and j and i again denoting sector and country.

$$\mathrm{NEI}_{ij} = \frac{X_{ij} - M_{ij}}{X_{ij} + M_{ij}}$$

Of other related trade measures, the export to import price ratio (Bojdnec 2003) takes quality differences between exports and imports into account. The Grubel-Lloyd measure corrects for simultaneous exports and imports of the same product.

Other macroeconomic measures of competitiveness

Several other measures of competitiveness on the macro level have been developed and employed. These are summarised in Table 1.

Table 1 Overview of other macroeconomic measures of competitiveness

Measure	Developer reference
Equilibrium exchange rate	Barrell et al. (2005)
Growth in market shares for exports	Fagerberg (1988)
Growth in relative unit labour costs	Kaldor (1978)
Net exports	Mulatu (2004)
Market share	Sharpe (1985)
Share of foreign direct investment	Sharpe & Banerjee (2008)

Microeconomic perspective

Revealed comparative advantage and relative export advantage

First formulated by Balassa (1965) and modified by Vollrath (1991), the measure revealed comparative advantage and relative export advantage (RCA or RXA), by using exports of a commodity compared to all other commodities to evaluate competitiveness. The measure calculates the ratio between a country 's export share of a commodity to the same country's export share of all other commodities. Also import based measures have been developed and used as well as utilizing the difference between export and import indexes. For a given commodity j and country i, RCA or RXA is defined as follows:

$\mathrm{RCA{=}RXA} = \left(\frac{X_{ij}}{X_{ik}}\right) / \left(\frac{X_{nj}}{X_{nk}}\right)$, with exports (*X*), *k* is all other commodities and *n* is all other countries.

Domestic resource cost

The domestic costs ratio (Bruno 1965) compares the value added from of a good that could be exported with the value of the inputs used to produce it. It can indicate whether domestic production is competitive in an international market. Specifically, it is the ratio between the value of domestic resources used divided by the sales price less the internationally traded resources used measured at border prices. This is shown in the following formula, where *l* and *P* are quantity and price of inputs to produce one unit of commodity *j*. *l* from 1 to *n* indicates traded inputs and *l=k+1* to *n* indicates non-traded inputs. *D* and *B* indicates domestic and border prices, respectively.

$$\mathrm{DRC}_j = \frac{\sum_{l=k+1}^{n} a_{jl} P_l^D}{P_j^B - \sum_{l=1}^{k} a_{jl} P_l^B}$$

Social cost-benefit ratio

The DRC is argued to understate the competitiveness of goods that predominantly use tradable input factors. To correct for this, Masters and Winter-Nelson (1995) proposed using the so-called social cost-benefit ratio. This is defined as the sum of costs of non-tradable inputs and tradable inputs divided by the export price of the good in question.

$$\mathrm{SCB}_j = \frac{\sum_{l=k+1}^{n} a_{jl} P_l^D + \sum_{l=1}^{k} a_{jl} P_l^B}{P_j^B}$$

Cost of production

Comparing production costs was suggested by Dornbusch (1980) and expanded on by Gallagher et al (2009). Countries with less production costs have competitive advantages. Here they include not only pure production costs, but also the marketing and transportation and other costs incurred to get the product to the buyer.

Profitability measurement

Some authors have used profitability measures as indicators of competitiveness. Positive profits may indicate that firms are able to generate barriers to entry and maintain their market shares. This would require some form of competitive advantage.

Other microeconomic measures

Several other measures of microeconomic competitiveness have been developed and employed in various studies. These are summed up in Table 2.

Table 2 Overview of other microeconomic measures of competitiveness

Measure	Developer reference
Composite, multi-variable	Buckley et al. (1992)
	Porter (1990)

Price competitiveness	Durand & Giorno (1987)
	Jorgenson & Kuroda (1992)
Unit labour cost	Hickman (1992)
	Turner & Golub (1997)
	Neef (1992)
Change in market share	Krugman & Hatsopoulos (1987)
	Mandeng (1991)
Industrial mastery, unit cost	Oral (1993)
Full unit cost	Siggel & Cockburn (1995)
Price/product attribute	Swann & Taghavi (1992)
Firm-level productivity	Altomonte et al. (2012)
Industry balance of trade	Zhang et al (2012)
Relative unit export price	
Relative export growth	
RCA for agro-food chains	Van Rooyen et al. (1999)
Trade balance	Buckley et al (1988)
	DeCourcy (2007)

Results

We have done an extensive literature search to find peer-reviewed papers that evaluate competitiveness within the seafood industry. For this task, Google Scholar was searched for the terms competitiveness, competitive and comparative advantage combined with seafood, fisheries, fish and aquaculture. The names of the various methods for calculating competitiveness have also been searched for, combined with the introduced industry terms. Citing articles of important method describing papers and reports have also been searched for the industry terms.

In all, 43 papers were identified through this process. We have grouped them according to the main thematic methods described in the introduction and these are presented in more detail in sub-chapters below. Summing up, we found a total of 32 papers employing the trade-driven measures developed around the "revealed comparative advantage" concept, whereof 19 employing relative comparative advantage (RCA), eight applying the concept of relative trade advantage (RTA) and five using relative export advantage (RXA). The trade-driven concept of constant market share (CMS) was used in 10 studies, eight papers were based on comparison of domestic resource costs (DRC), and two studies each focused on export competitiveness (XCI) and full unit cost (FUC). Studies have also been undertaken using the framework of Buckley et al. (1992), the Porter diamond and flexibility theory (Porter, 1990), data envelopment analysis (DEA), and relative unit costs (RULC) and relative producer prices (RELPR).

The studies vary in what level and industry scope they investigate. Most of the identified studies look at aquaculture (20), mostly shrimp, while 12 studies examine seafood in general and 11 specific fish species, mainly tuna. The industry level also varies strongly between studies – from studies investigating the whole aggregated seafood sector of a country to individual farms being the subject.

Several of the studies employ more than one measure of competitiveness. However, most of these use strongly linked methodologies – such as both calculating the relative comparative advantage and the relative trade advantage. Only one study was found to employ methods that are widely different.

The geographic area under scrutiny also varies strongly. Most studies cover a range of countries, especially several or all EU countries, Asian or countries from the whole world. None investigated countries from South-America. India stands out as the single county with most studies, even surpassing the studies covering a range of countries. The same pattern is found for the RCA-type studies. The DRC-concept focuses more strongly on lower geographical levels, even single counties/provinces are represented here. The CMS-type studies are relatively equally distributed between different geographical levels, but again India is strongly represented. The results are summarised in Table 3.

Table 3 Classification of studies according to geographic region and level

	RCA-type	DRC-type	CMS-type	Other	Total
Several EU	5			1	7
Several Asia	3	2	1	1	7
Several world	5		1	1	6
India	5	1	2	1	10
Vietnam	1	1			2
Thailand				1	1
Iran		1			1
Italy			1		
USA		1			1
Indonesia	1		1		2
Province India			1		1
County USA		1			1

Table 4 illustrates that there is also some variability in terms of which markets the studies are focusing on. A strong majority have the world market as benchmark for trade. The remainder of the studies are more evenly distributed between markets such as EU, major markets for the products under investigation and single country markets.

Table 4 Classification of studies according to which market competitiveness is evaluated in

	RCA-type	DRC-type	CMS-type	Other	Total
World	13	2	1	2	18
EU	3	1			4
Asia	1		1		2
Major markets	1		2	1	4
Japan	3	1			4
USA	2	1	1		4
Spain			1		1

Studies vary in the level of detail of the products in question. Most studies do not report HS og SITC classification of this, so we have classified them somewhat subjectively in categories shown in Table 5.

The highest level of detail is specific products, such as "fresh sardines". Product groups includes when species are defined, but not the processing type, e.g "catfish", or when several specific products are grouped together, e.g "fresh, live or frozen tuna". Seafood sector is employed when the study investigates the whole sector, including all products. Broad category is used for groupings that fall between sector and product groups.

Most studies are concerned with product groups, but closely followed by specific products. About 1/5 have the sector in respective countries as their research area. This description is in general valid also for the RCA-type analyses, but the DRC studies naturally focus on a more detailed product identification. Most CMS-type studies have employed fairly detailed trade data at product group level. The results are summarised in Table 5.

Table 5 Classification of studies according to product level detail

	RCA-type	DRC-type	CMS-type	Other	Total
Seafood sector	3		1	2	6
Broad categories	3				3
Product groups	7	6	4		17
Specific products	9	1	1		11

Species that are investigated are presented in

Table 6. To a certain extent, this is related to the countries and where there is data available. For some of the observations, the actual species is not stated, rather animal family is indicated, and in some cases higher level categories are stated. This is reflected in our classification. Of the studies where species is specified, the vast majority are analysing shrimp. This is true both for RCA and DRC-concepts. For the former, there are several other species being investigated, while the DRC studies are limited to relatively high quantity aquaculture species catfish and eel. The CMS-approaches have a large range of species under study.

Table 6 Classification of studies according to "species"

	RCA-type	DRC-type	CMS-type	Other	Total
Sardine/Anchovy	1		1		2
Tuna	6		2		8
Sea bream	1				1
Shrimp	5	4	1		10
Catfish		2			2
Eel		1			1
Cephalopods			1		1
Ornamental	1		1		2
Most important exports	2				2
No data	5		1	2	8

Table 7 and Table 10 below present the individual seafood articles we have identified and that underlie the previous discussion of various aspects of the studies.

Table 7 Studies employing competitiveness concepts related to revealed comparative advantage and relative export advantage

Method / Study	Study title	Explicit measure	Comparison	Sector	Species/product group	Time
Camanzi et al 2012	Competitiveness of Italian small pelagics in international trade	RXA CMS	Italy, France, Spain and Morocco in world market	Fish.	Sardines and anchovies, fresh/frozen and processed	1990-2008
Crescimanno & Galati 2012.	The Atlantic Bluefin tuna: structure and competitiveness	RTA	Italy vs other suppliers in world market	Fish.	Fresh, live and frozen tuna	2004-2006 and 2007-2009
Kaimakoundi et al 2014.	Investigating export performance and competitiveness of Balkan and eastern European fisheries sector.	RCA	Several countries in EU market	Seaf.	Most important products exported from each country	1999-2011
Supongpan Kuldilok et al. 2013.	The export competitiveness of the tuna industry in Thailand	RCA	Large supplier countries in world market and supplier countries in large markets	Fish.	Canned tuna	1996-2006
Kumar 2004.	Export performance of Indian fisheries.	RCA RSCA (symmetric)	India in world market	Seaf.	Seafood product groups	1983-2000

Polymeros et al. 2006.	Assessing the competitiveness of EU Mediterranean fisheries and aquaculture	RCA	France, Italy, Greece, Portugal and Spain in EU market	Seaf.	Seafood, grouped in 6 product categories	1993-2003
Rani et al. 2014.	Ornamental fish exports from India: Performance, competitiveness and determinants.	RCA RTA CMS	RCA for India, RTA for 6 major suppliers in world market	Aq.	Ornamental fish	1991-2009
Oikonomou & Polymeros 2015.	Analyzing the Competitiveness of the Greek Sea Bream Exports in the European Union Market	RXA	EU producers in 8 major markets	Aq.	Sea bream	2000-2013
Navghan & Kumar 2017.	An Empirical Assessment of Indian Seafood Export Performance and Competitiveness	RCA RTA RXA	India in world market	Seaf.	Seafood	2001-2015
Rani & Kumar 2016.	Status and Competitiveness of Fish Exports to European Union	RCA	India in EU market	Seaf.	Total and 7 product categories	2000-2014
Pavithra et al 2014.	Market shares, instability and revealed comparative advantage of seafood exports from India	RCA XCI	10 major producers in world market	Seaf.	Shrimp	1991-2009
Navghan et al 2017.	An Empirical Assessment of Seafood Export Performance and Competitiveness in Gujarat, India	RCA XCI RTA	Gujarat and India in world market	Seaf.	Seafood	2001-2015
Ismail and Abdullah 2013.	Shrimp trade competitiveness of Malaysia and selected ASEAN countries	RTA	Malaysia and ASEAN countries in world market	Aq.	Shrimp product categories	

Khai et al 2016.	Consistency tests of comparative advantage measures: An empirical evidence from the Malaysian and selected Asian shrimp products	RCA RTA	Malaysia and ASEAN countries in market defined by same countries	Aq.	Frozen, non-frozen and prepared shrimp	1999-2009
Gopal et al. 2009	Indian Finfish Exports – An Analysis of Export Performance and Revealed Comparative Advantage	RCA RTA	India in world market	Seaf.	Finfish total and 9 selected finfish products	2001-2005
Kiet and Sumalde 2008.	Comparative and competitive advantage of the Shrimp Industry in Mekong River delta, Vietnam	RCA	Vietnam in world market	Aq.	Frozen shrimp	2001-2005
Ling et al. 1996	Export performance of major cultured shrimp producers in the Japanese and US markets	RCA	Nine producer countries to Japan and US	Aq.	Frozen, live, fresh, salted shrimp	1989-1991
Kijboonchoo and Kalayanakupt 2003.	Comparative advantage and competitive strength of thai canned tuna export in the world market	RCA	Major exporters to world market	Fish.	Canned tuna	1982-1998
Apridar 2014.	The competitiveness of Indonesian tuna export facing the ASEAN economic community	RCA	Major ASEAN producers to world market	Fish.	Tuna	2005-2009
Hidayati et al. 2015.	Analysis of determinant Indonesian tuna fish competitiveness in Japanese market	RSCA	Indonesia in Japanese market	Fish.	Fresh, frozen and preserved tuna	1989-2012

Yusuf et al 2018.	Analysis of competitiveness on Indonesian tuna export commodities in Japan and USA	RCA	Indonesia in Japan and USA	Fish.	Tuna	2009-2015

Table 8 Studies employing competitiveness concepts related to domestic resource cost

Method / Study	Study title	Explicit measure	Comparison	Sector	Species/product group	Time
Esmaeli 2008.	Measuring competitiveness of shrimp farming in southern Iran: Using PAM approach.	DRC	Farms in Southern Iran	Aq.	Fresh shrimp	2004
Kaliba & Engle 2003.	Impact of different policy options on profits of private catfish farms	DRC	Farms in county	Aq	Catfish	2001
Hanson et al. 2013.	Comparative advantages of the US farm-raised catfish industry.	DRC	Catfish industry	Aq	Catfish	2005-2009
Lee et al. 2002	The competitiveness of the eel aquaculture in Taiwan, Japan, and China	DRC	Taiwan, Japan, China	Aq.	Eel	1990 and 1993-99
Ling et al. 1999	Comparing Asian shrimp farming: the domestic resource cost approach	RCR	Asian supplier countries in Japan, US and EU market, three production strategies	Aq.	Shrimp	1994

Kiet and Sumalde 2008.	Comparative and competitive advantage of the Shrimp Industry in Mekong River delta, Vietnam	RCR	RCR for two provinces and production strategies	Aq	Shrimp	2005
Shang et al. 1998	Comparative economics of shrimp farming in Asia	RCR	Asian supplier countries in Japan, US and EU market, three production strategies	Aq.	Shrimp	1994
Debnath et al 2009.	Resource use efficiency and social profitability of an integrated aqua-farm, Tripura, India	RCR	Integrated and specialized single farms	Aq		

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Table 9 Studies employing competitiveness concepts related to constant market share

Method / Study	Study title	Explicit measure	Comparison	Sector	Species/product group	Time
Singh & Dey 2011.	International competitiveness of catfish in the US market	CMS	Major exporters to US market	Aq.	Catfish	1989-2008
Camanzi et al 2012	Competitiveness of Italian small pelagics in international trade	RXA CMS	Italy in Spanish market	Fish.	Sardines and anchovies, fresh/frozen and processed	1990-2008
Somasekhharan et al 2013.	Coping with the standards regime: Analysing export competitiveness of Indian seafood industry	CMS	India to major world markets	Seaf.	Shrimps and cephalopods	1996-2007
Suhana et al. 2016.	Tuna industries competitiveness in international market. Case of Indonesia.	CMS	Indonesia in world market	Fish.	Tuna product groups	1998-2014.
Rani et al. 2014.	Ornamental fish exports from India: Performance, competitiveness and determinants.	RCA RTA CMS	MS for India in 5 major markets	Aq.	Ornamental fish	1991-2009
Klasra and Fidan 2005.	Competitiveness of major exporting countries and Turkey in the world fishery market: A constant market share analysis	CMS	Major exporting countries and Turkey in world market	Seafood	Seafood exports	1980-2000

Camanzi et al 2012	Competitiveness of Italian small pelagics in international trade	RXA CMS	Italy in Spanish market	Fish.	Sardines and anchovies, fresh/frozen and processed	1990-2008
Apridar 2014.	The competitiveness of Indonesian tuna export facing the ASEAN economic community	RCA CMS	Major ASEAN producers to ASEAN market	Fish.	Tuna	2005-2009

Table 10 Studies employing other competitiveness concepts

Method / Study	Study title	Explicit measure	Comparison	Sector	Specie/product group	Time
Buckley et al (1992) or Porter (1990) composite						
Fischer and Schornberg 2007	Assessing the competitiveness situation of EU food and drink manufacturing industries: An index-based approach	Composite index		Seaf.	Seafood category	1995-2002
Sagheer et al. 2007	Assessing international success and national competitive environment of shrimp industries of India and Thailand with Porter's diamond model and flexibility theory	Composite index		Aq.	Shrimp	Not stated
Relative unit costs and producer prices						
Mbaye and Golub 2007.	Senegalese manufacturing competitiveness: A sectoral analysis of relative costs and prices	RULC RELPR	Senegalese sectors compared to main competitors	Seaf.	Fish processing	1974-1998
Efficiency/Productivity						

Shang et al. 1998	Comparative economics of shrimp farming in Asia	DEA	Asian producer countries	Aq.	Shrimp	1994
Full unit cost						
Bjørndal 2002	The competitiveness of the Chilean salmon aquaculture industry		Chile and Norway	Aq.	Salmon	
Ridler 1994	Globalization and Trade in Renewable Resources A Case Study of Farmed Salmon		Chile and Canada to US market	Aq.	Salmon	

Discussion

Early developments in economics in the 17th and 18th centuries form the basis of the competitiveness concept and measurements of it. High rates of development in transports and communications have strengthened competition in many commodity producing sectors and highlighted the need for countries to allocate resources effectively and use them efficiently to improve living standards.

Competitiveness itself is a fuzzy concept, where there is no general agreement on definition. Consequently, several methods have been developed in order to measure it. Trade and economic performance indicators are the most commonly used, but also other approaches such as multidimensional indices are employed.

Acknowledging that all methods have weaknesses and are unable to capture the nature of competitiveness, many studies employ more than one analysis to allow for a better description and interpretation of the subject. Choices of methods are also often dependant and restricted by data availability.

Here, we have made a comprehensive search in the peer-reviewed literature for studies of competitiveness within the seafood sector. Compared to economically larger sectors, the number of published papers is relatively small. There are relatively small overlaps between the studies. Few have looked at similar products from the same countries in the same markets with methods that differ considerably. Hence, we do not consider the material to allow for comparisons or other analyses that could yield interesting and useful results and be interesting for a journal to publish.

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Part 2 Production cost and competitiveness in major salmon farming countries 2003-2015

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Introduction

It is well known that productivity growth leading to reduced production cost and improved competitiveness is a key factor in the success of modern aquaculture (Asche, 2008; Kumar and Engle, 2016). Size of market share or changes in market share indicates the end result of competitiveness (Mandeng, 1991). The concept of competitiveness is, however, not well defined in literature, and several indicators have been developed and employed, such as export performance, price ratios and multidimensional indicators (Siggel, 2006). In this paper, we investigate competitiveness through the development of unit production costs in the main producer countries of Atlantic salmon.

While production of most aquaculture species takes place in several countries, there are few studies that compare the development in competitiveness or production cost in different countries. A main reason for this shortcoming is that cost data for both firms and the farming industry is hard to come by, and data that are somewhat comparable between different countries are even less available. In this paper, we have access to a unique data set on production cost for Atlantic salmon in the five largest salmon producing countries for the period 2003-2015. The data enables us to compare the development in production cost in the five countries over time and to associate this with production growth. This is a particularly interesting period for salmon aquaculture, as there have been substantial changes in production shares between different countries, with disease outbreaks and impacts of regulations as major explanatory factors.[4]

Atlantic salmon (*Salmo salar*), hereafter just salmon, is a particularly interesting species to study for several reasons.[5] It is one of the most successful aquaculture species, with a higher production growth than for aquaculture in general (Kobayashi et al, 2015). This is to a large extent due to the fact that salmon producers are in the forefront in a number of productivity enhancing categories such as production technology and supply chain development (Smith et al., 2010; Kumar and Engle, 2016; Asche et al., 2018c; Kumar et al., 2018). Salmon is also produced in relatively few countries exposed to different economic shocks and with substantial geographical dispersion and considerable differences

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[4] However, it is worthwhile to note that there is a well integrated global market so that the price development is similar in the main production countries (Asche et al, 2018a).

[5] Atlantic salmon is the most important farmed salmon species by quantity, although significant quantities are also farmed of coho and trout, and smaller quantities of other species. In 2015, 86% of the production of farmed salmon was Atlantic (FAO Fishstat).

in biophysical conditions. Five countries made up 95.6% of the production in 2015. Norway is the largest with a production share of 55.3%, and is together with Scotland (7.6%) and the Faroe Islands (3.3%) in Europe. The second largest producing country Chile (25.4%), is located in South America, and Canada (6%) in North America. The remaining 4.4% is spread among eight countries with severe limitations to their production capacity due to availability of appropriate sites. Hence, there are relatively few countries that can make up production shortfalls in any specific country, and substantial production shortfalls in any specific country can have a significant market impact.

There have been a number of shocks to the market that likely influenced the various producer countries differently. The most important is a serious disease outbreak in Chile that climaxed in 2010. Chilean production was reduced by two thirds to 129 thousand tonnes in 2008 (Asche et al., 2009; Fischer et al., 2017; Quesada and Dresdner, 2017). However, the relative prices between producers and market did not change, demonstrating that there is a well-integrated global market for salmon (Asche et al., 2018a). Hence, while the disease issues were highly problematic for Chile, it was largely beneficial for producers in the other countries through increased prices (Asche et al., 2018b). In addition, there are substantial concerns with respect to environmental impacts in all five major salmon producing countries that limit access to new production sites and increases in license capacity. With increased demand as shown in Brækkan et al. (2018), this further contributes to higher producer prices.

Feed is the most important input factor in salmon aquaculture with a cost share of over 50% (Guttormsen, 2002; Asche and Oglend, 2016). Prices for the most important ingredients, fish meal and fish oil, are highly volatile and influenced by *El Ninos* (Oglend, 2013; Ubilaya, 2014). Longer trends like climate change (Lorentzen, 2008; Hermansen and Heen, 2012) and regulatory system (Abate et al., 2018; Osmundsen et al., 2017; Nadarajah and Flaaten, 2017; Murray and Munro, 2018) have been shown to influence production costs. With the geographical dispersion of the salmon producing countries, these trends are likely to have different country-wise impacts. The prevention and treatment of sea lice has become a major cost component (Abolofia et al., 2017), likely to influence countries differently. Disease prevalence and impacts often have major cost implications, and the different producer countries have faced different challenges in this area in the period under study.

The only study we are aware of that compares developments in productivity growth for salmon is Asche et al. (2003), placing salmon aquaculture within the general framework of Siggel and Cockburn

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(1995).[6] They discuss how production shares reflect differences in productivity development corrected for regulatory impacts and show the development for the four largest salmon producing countries. However, as they acknowledge, production shares are only a proxy for production cost, as the causality normally goes from production cost to production shares. There are several factors indicating that the link between production cost and production shares is not a direct one. Salmon is sold in different geographical markets, with different transportation costs to serve the market for different producer nations, and in different product categories (fresh, frozen, processed etc.). Supply is also influenced by natural conditions, biological issues and by regulations. With the high prices experienced in recent years, all expansion in production would be profitable. However, production increase has been limited by access to new sites or limits to capacity in existing sites. In addition, increased supply comes with a certain time lag, as the entire production cycle from broodstock to harvest takes 3-4 years. Currency changes may also have a significant impact on competitiveness between the five countries. We have chosen USD as a reference as this is the trading currency for both American and Far-East markets. It should be noted that most of the salmon from Norway, UK and the Faroe Islands is sold in Euro[7].

The paper is organized as follows: The production of salmon is presented first, with focus on historical development among producer countries. Next, production costs in the same countries are discussed, focusing on explanatory factors.

Salmon production

The produced quantity of salmon in the five countries investigated here, which makes up over 98% of total production, is shown by country in Figure 1 for the period 1990-2015. Production has been rapidly increasing from 230 thousand metric tons (mt) in 1990 to 2.2 million mt in 2015. It is noteworthy that all the countries show a strong growth in production, although with variations in the growth rate through the period under study. This is not surprising given the rapid production growth for the industry. The impact of the disease challenges in Chile is clearly visible around 2010, although it is worthwhile to note that by 2012 total production is back on the long run trend. Norway has been the main producing country throughout the period. This is even clearer in Figure 2, where the production shares are shown. Norway´s production share of 65.7% in 1990 is the highest measured in the data set, while the lowest Norwegian production share (41.7%) was recorded in 2001. Since 2001 Norway's

[6] Bjørndal and Aarland (2003) provided a comparison of production cost in Norway and Chile, without being able to say anything about the development over time.

[7] Straume (2014) provides an overview of the exchange rates used by Norwegian salmon exporters.

production share has been increasing gradually, with the exception of a strong short term gain and loss during and after the disease crises in Chile. Chile's production share increased rapidly in the 1990s, but has been stable with considerable variation around the mean in the 2000s. The UK´s production share is the only showing a consistent decline, although also Canada´s has declined in the 2000s.

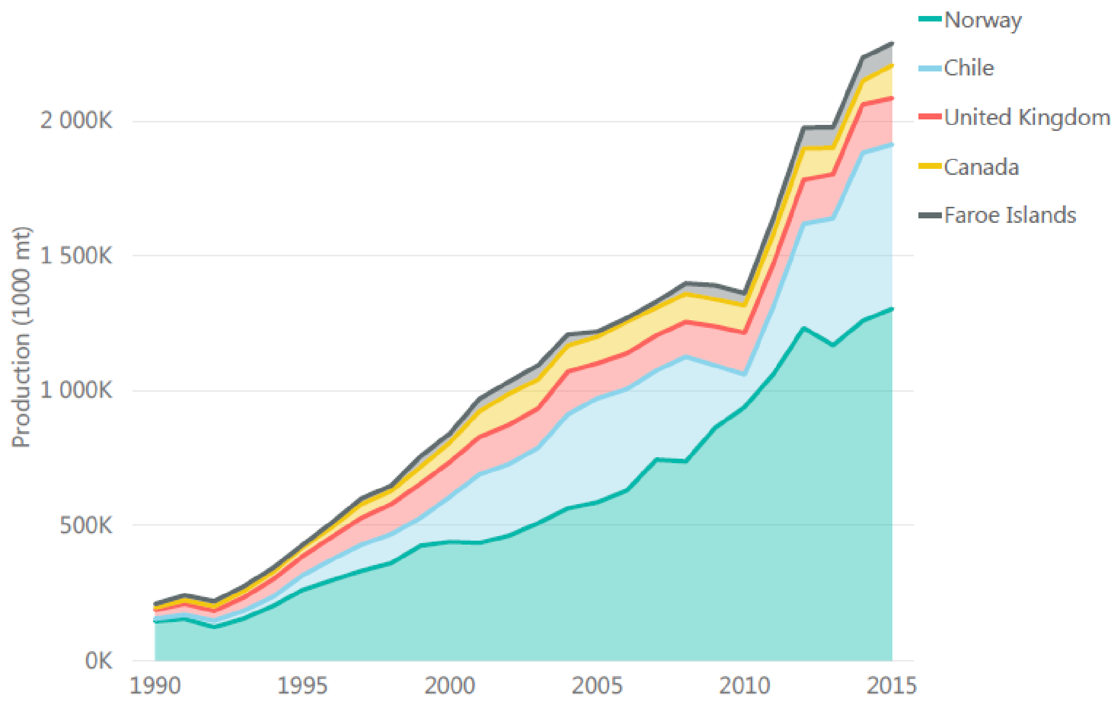

Figure 1 Salmon production of Norway, Chile, United Kingdom, Canada and the Faroe Islands 1990-2015. Thousand metric tonnes.

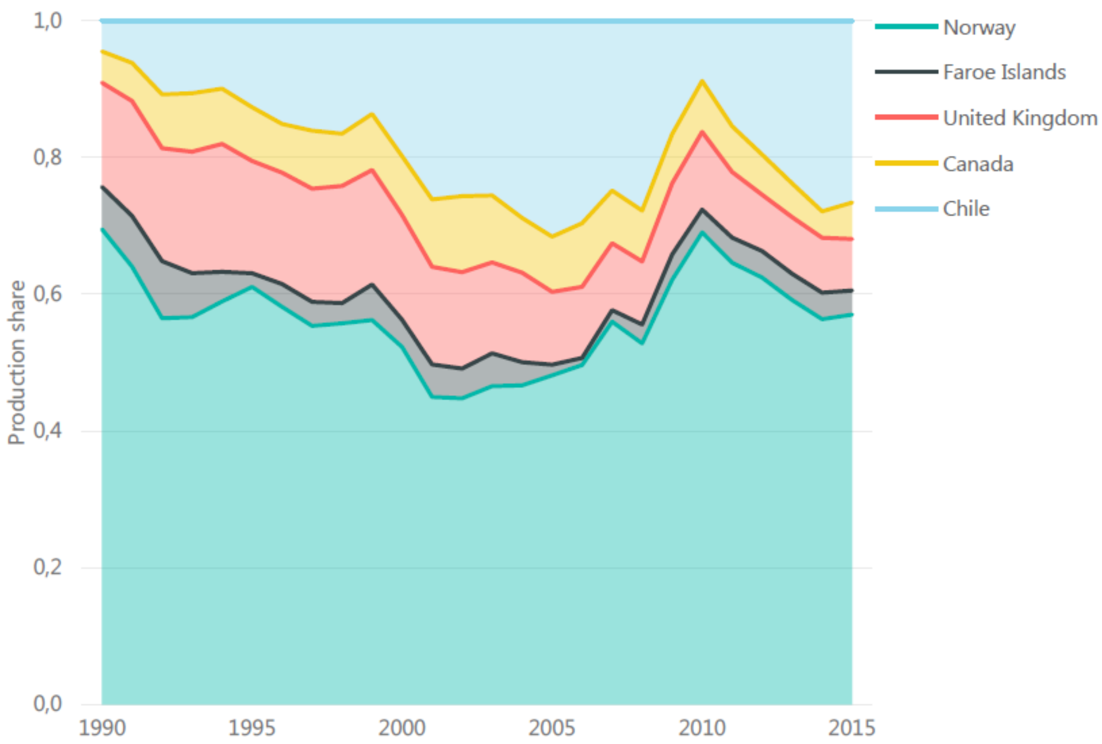

Figure 2 Relative salmon production of Norway, Chile, United Kingdom, Canada and the Faroe Islands 1990-2015.

Data availability has been relatively good in Norway, and Asche (1997) reported the first relationship between price, production cost and quantity produced. In real terms, the production cost in 2016 was about a third of what it was in 1985, as was the price. This is the relationship one would expect in a growing competitive industry.

A number of productivity studies have been conducted on Norwegian data, with Vassdal and Holst (2011), Nilsen (2010), Asche et al. (2013a), Asche and Roll (2013) and Roll (2013) as some recent examples.[8] The main long-term results from these studies can be summed up as substantial technologically non-neutral technical progress that is slowing down, leading to an increasing cost share of feed. However, recent data indicate that during the last five years, this trend has been broken. Cost composition is stable, with both feed cost and other costs rising, primarily due to increasing feed prices and biological issues related to parasites and diseases. While one can still observe significant

[8] Sandvold and Tveteras (2014) and Sandvold (2016) show that there has also been significant productivity growth in the production of smolt.

investments in technology, leading to technological progress, this progress is overshadowed by biological problems related to lice and disease as well as increased costs associated with better capacity utilization due to the high prices. The technical change also increases the efficient scale (Asche et al., 2013b), and there still appears to be unexploited scale economies in most countries. Even though production technology is similar, there are considerable differences in site-level scale and physical conditions, regulations and capital intensity (Iversen et al. 2016).

Data

Salmon farming companies generally do not report unit cost data. Norway is an exception in that salmon farmers are required to provide the authorities with relatively detailed annual accounting and production data, allowing for comprehensive calculation of unit costs and published in an annual publication provided by the Directorate of Fisheries (Directorate of Fisheries, 2018). Such data are not available for other countries. The seafood statistics and analytics firm Kontali Analyse AS employs a cost model to estimate unit costs (unit hereafter reflects per kg produced) in each country to provide such data. This model is based on data from several sources and seeks to reflect country averages. Annual accounting data for all available salmon producing firms are collected when available and data on firm production is obtained from various sources, primarily annual accounting reports. Several firms have activities in sectors other than pure salmon farming, requiring the accounting data to be adjusted to reflect only the salmon farming activity. Information on smolt release, prices and yield are collected from different public sources, as well as from interviews with key stakeholders, providing the basis for estimating smolt unit costs. Feed prices are estimated using both public and interview data and combined with information on biological performance such as mortality and feed conversion rates. Other costs are estimated in a similar fashion. The model is calibrated against the annual accounting reports. Resulting cost estimates are also triangulated against the relatively detailed public reports from firms listed at stock exchanges. For Norway, the model is populated every year, whereas in the other countries where data is less publicly available, data have been collected every third year. Representativity is ensured through a thorough check of data on smolt production, feed use, mortality, sales etc.

Results

For the analysis, US dollars (USD) are used as common currency to facilitate comparisons across countries.[9] Real unit production cost is shown in figure 3 for every third year from 2003. Cost levels and development differs considerably between countries. None of the countries show a clear and stable trend in cost development, instead costs move both up and down between years. In Norway, Scotland and Canada costs change relatively little over the whole period, but with considerable changes in each three-year-period. Norway's costs are at a lower level than Canada and Scotland during the whole period. Scotland starts out with close to the highest costs, improves until 2009 and then increases again to have close to the highest cost. Canada starts out with slightly higher than average costs that continue to rise until 2012, when it is the highest cost producer. In the final period, Canada sees a major improvement in costs to lower than average in 2015 and maintain their number three position.

The two countries that clearly stand out are Chile and the Faroe Islands, with generally opposite developments, and for both countries significant disease outbreaks is a major factor in the cost development. Chile starts out as the lowest cost producer, then seeing rapid cost increase in both 2006 and 2009, before improving a bit in 2012 and increasing again to become the highest cost producer in 2015. The Faroe Islands not only have a declining production cost, but actually moves from being the highest cost producer in 2003, to having the lowest production cost in 2015. The main reason behind this anomalous development is that the Faroe Island had a major ISA outbreak just after the turn of the century where production was more than halved and resulting inflated costs. As such, Chile is far from being the only country where disease outbreaks have had major impacts on production. The main difference is that Chile's production was so high that the impact of the disease outbreak was felt globally. Throughout the sample, Canada and the UK are high cost producers, and as such, their declining market shares may not be too surprising.

Chile´s production cost is significantly influenced by disease. The relatively strong increase from 2003 to 2006 gives additional evidence to the stagnating production growth that there were serious disease issues well before the ISA was reported in 2007, as discussed e.g. by Asche et al. (2009). While 2009 does not quite coincide with the most dramatic disease year (2010), it is still clear that the disease

[9] It should be noted that salmon is sold in other currencies as well, notably most of sales to European countries are in Euro. Actual production decisions will be influenced by exchange rates in local currency as well. Tveteras and Asche (2008) show that due to highly efficient exchange rate markets, it does not matter which currency the price is denoted in for comparison purposes. Straume (2014) provide a detailed overview of currency use in Norwegian salmon exports.

issues made Chile go from having a clear cost advantage to becoming the highest cost producer for a limited period of time. Moreover, for various reasons, including an algae bloom in 2016 and costs associated with improving biosecurity and tighter regulations, Chile remained a higher cost producer after the disease outbreak. This largely explains why the Chilean production share does not increase after the ISA outbreak was brought under control.

Norway is among the two lowest cost producers throughout the period. In 2003, Chile had significantly lower production cost, while Norway has the lowest production cost in 2006 and 2009, a period when it´s production share grows rapidly and Chile and the Faroe Islands are going in and out of their respective ISA-crises. In 2012 and 2015 the Norwegian production cost is higher than the Faroe Islands, but still considerably lower than for the other three countries. Hence, with the limited capacity of the Faroe Islands, Norway´s position as the leading salmon producing country over time seems justified by its low production cost. However, it is also clear that access to sites, site capacity and legal production constraints matter. In particular, one would expect the Faroe Islands production share to increase if more sites were available. The Faroe Islands also face other constraints to their production, such as shallower depths on the sites and a limit to the number of smolts released per site. While nets in the Faroe Islands are 10-20 meters deep, cages of the same size in Norway will typically have nets 40-50 meters deep.

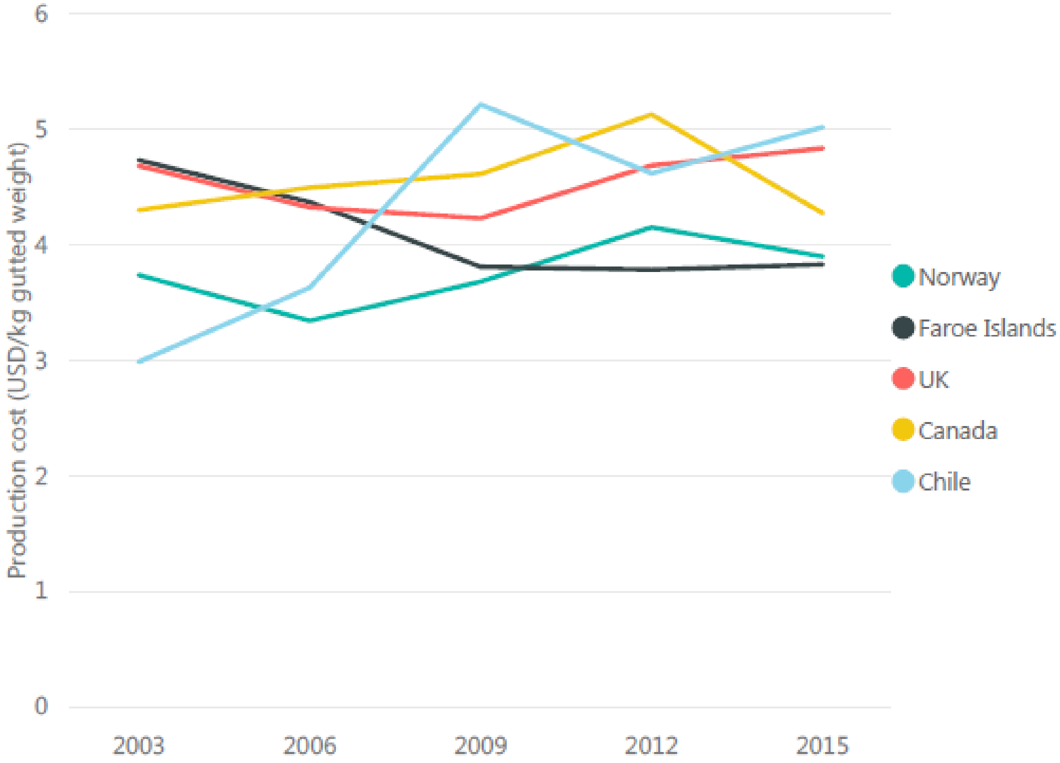

Figure 3 Production costs (USD/kg gutted weight) of salmon production in Norway, the Faroe Islands, UK, Canada and Chile.

In Figure 4, the unit cost is broken down by main cost categories in 2003 and 2015. The cost structure is relatively similar between the countries, with feed as the clearly most important input factor. The importance of feed has increased in the period, with increases in unit cost ranging from 0,05 to 0,27 USD/kg excluding Faroes where the disease issues have seen costs decreasing by 0,52 and Chile increasing by 0,97 due to disease outbreaks. This indicating that the other factors have become more intensively used. This gives support to the notion of Guttormsen (2002) that feed is the only variable input factor. Smolt costs are generally reduced and labor relatively unchanged. Miscellaneous costs, however have increased strongly, both in absolute and relative terms. At least in Norway, this is primarily due to the lice treatment costs and a trend towards outsourcing of operational activities such as net pen cleaning and inspections as well as increasing overhead costs. In addition, it is worthwhile to note how Chile has gone from being a clear cost leader for smolt and feed to have the highest cost in both categories, and in addition, Chile has also become the highest cost producer for miscellaneous operating costs.

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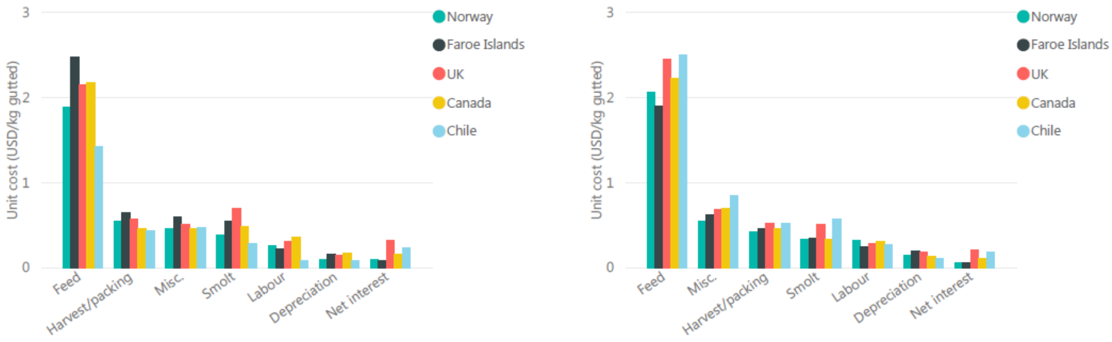

Figure 4 Unite operating costs (USD/kg gutted weight) in Norway, the Faroe Islands, UK, Canada and Chile in 2003 (left) and 2015.

The smolt cost per kilo is determined by price per smolt, weight at harvest and losses. Smolt yield is the quantity of fish produced per released smolt. As shown in Figure 5, smolt yields has generally been stable over time, with notable exceptions for Chile and the Faroe Islands,. From 2004G[10] and onwards, the Faroe Islands smolt yield improves significantly as they regain healthy production after an ISA crisis, and it surpasses all other producing nations primarily due to much stronger bio-sanitary measures. The industry consolidated into three players after the crisis. These split production zones between them, and coordinated release, harvest and fallowing, resulting in production with much improved biological results. For Chile, the smolt yields again gives a strong indication that the disease situation was highly problematic a long time before the ISA-outbreak was announced in 2007. It is also highly interesting to note how the smolt yield improves for the generations that are harvested after the worst disease outbreaks had seen a strong reduction of the biomass at sea. For Canada, Norway and the UK, the smolt yields are relatively stable, but with a lower yield in the UK. This is at least partly due to higher water temperatures giving faster growth and higher turnover, shorter growth cycles and harvesting smaller fish.

[10] Smolts released in 2004 G=Generation

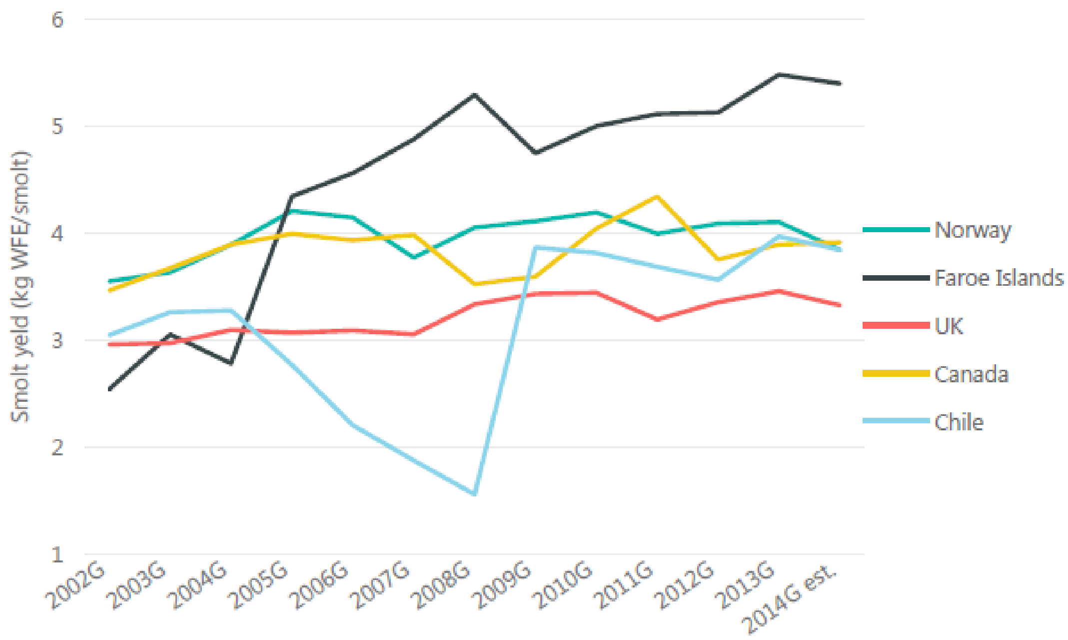

Figure 5 Smolt yield (kg WEF/smolt) in Norway, the Faroe Islands, UK, Canada and Chile.

Smolt cost may also be more important than indicated by the cost share, as the biological performance, particularly weight at harvest and losses in production, to a considerable degree depends on the quality of the smolt. Both weight at harvest and loss have strong implications for several of the other cost categories, and feed in particular. Hence, production losses are another important factor that influence production cost. Figure 6 shows losses in terms of share of the released individuals that are not harvested and sent to the market.[11] There are several reasons for these losses, including smolts that do not survive the transfer to seawater, damages during handling, losses to predators, disease, escapes, lice treatment etc. Early loss is less costly than later when the fish has consumed feed and other cost items.

The main story is again that the Faroe Islands and Chile differ from the others, due to the previously described disease outbreaks. However, also here it is clear how the Faroe Islands responded to the crises by instituting a much better governance system, among other adaptations, that results in much

[11] Loss measured as number of individual fish corresponds with cost increases only if the size composition of the fish that is lost is constant. This is not always the case. We know that the size of lost fish is increasing in Norway, due to lice treatment leading to mortality of larger fish, and assume this might be the case in other countries as well, but we do not have sufficient information to estimate this effect. Most losses appear to be relatively small fish, but the economic loss is of course much larger when it is large fish that escape, get diseases etc.

lower production losses than the other countries. The smolt number restrictions also likely make the farmers prioritize smolt quality and size more strongly.

The production loss levels in Canada, Norway and the UK are relatively stable, with Norway´s level clearly lower than the other two, and some improvement in the UK in recent years. It is also interesting to note that the production loss level in Chile has stabilized at a similar level as Norway after the disease crises.

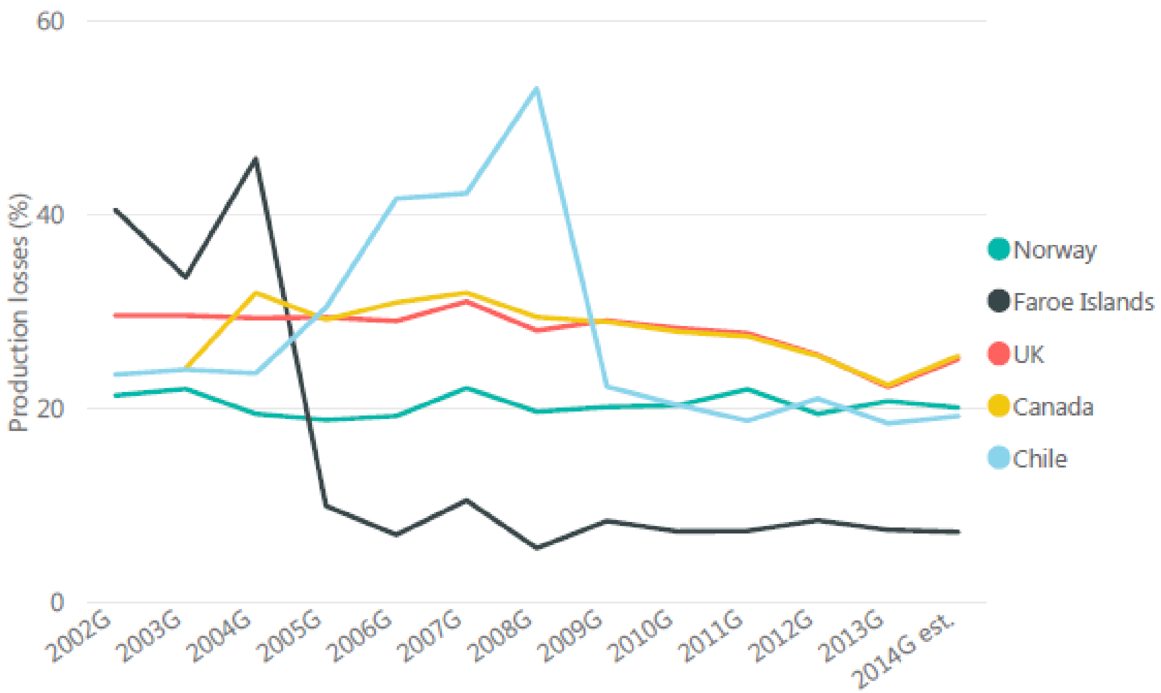

Figure 6 Production losses in % in Norway, the Faroe Islands, UK, Canada and Chile.

Feed conversion ratio (FCR) usually is the single most important biological indicator for economic performance, as it together with feed price defines the unit feed cost. In particular the economic FCR, describing the quantity of feed spent per kg of harvested fish. In Figure 7 the countrywise EFCRs are presented. For the last generation (2014G, harvested in 2015), we see that differences in EFCR corresponds quite well to production cost. Norway experienced a steady EFCR for a long period, until increased mortality due to lice treatment started to kick in. Scotland has over a long period seen improvement, except for the last year. We note though, that Norway and Scotland has a quite similar EFCR, even with much lower costs in Norway, which is probably explained by larger scale of operations and higher productivity in Norway.

Over time, we recognize the influence of biological crises on this indicator as well. The sharp decrease in EFCR for the Faroe Islands, in the wake of their ISA-crisis, is related to poor performance during the crisis and their improved biological practice thereafter. As mentioned earlier, the build-up of biological issues in Chile was not only related to ISA, and may be seen here as early as 2005. After the ISA-crisis, Chile stabilized at around the same level as Canada.

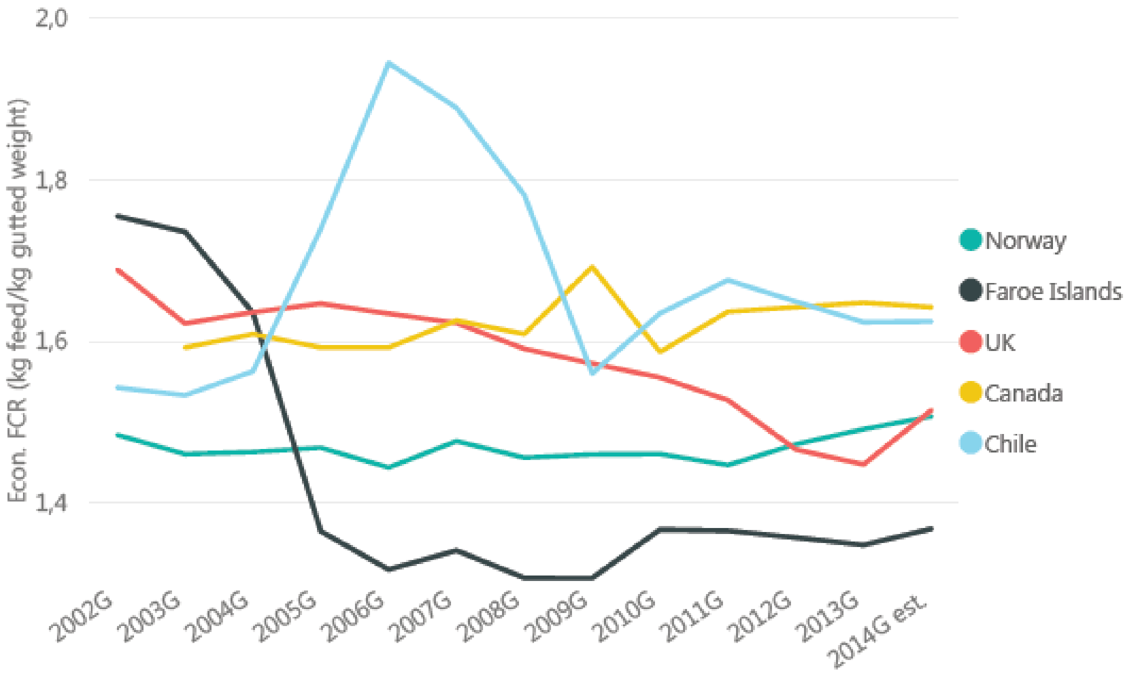

Figure 7 about here.

Concluding remarks

It is well known that there is a global market for salmon (Asche et al., 1999; 2018a), where most consumers do not care where the salmon originates from and movements in prices are closely aligned over time.[12] Hence, the production cost is a key measure of each salmon producing country´s competitiveness, although access to suitable production sites is vital for an industry´s ability to respond to a good competitive position.

A unique data set allow us to show the development in the production cost at a triennial frequency in the five most important production countries for farmed Atlantic salmon for the period 2003 to 2015. The most striking insight is that with the exception of the Faroe Islands, the real production cost measured in USD has been increasing in all countries, moderately so in Norway over the whole period and much so in Chile. This is in stark contrast to the relatively long previous period of declining production costs and increasing productivity. Secondly, for those two countries with major disease outbreaks, the Faroe Islands and Chile, these disease outbreaks dwarf any underlying trend. Thirdly, the cost composition is relatively similar in all the countries, and the lowest cost producer at any time tends to do well in all categories rather than being particularly good in one dimension. This may not be too surprising given that the production technology is similar in all countries.

During the 2010s the Faroe Islands not only have the lowest production cost, but they are also clearly better performing than the other countries on other important indicators such as feed conversion ratio and production losses. These are strong indications of better governance, and as the Faroe Islands is also the smallest of the five countries by quantity, it provides evidence that good governance is not dependent of industry size. Or, as in the case of the Faroe Islands, is more easily implemented with only three players. The largest producer, Norway, has the lowest production cost in some years when its production share is increasing, but generally comes out as a good number two in most categories. It is also interesting to note how, with the exception of when other countries are hit by a disease crisis, Canada and the UK are consistently scoring worst. It may than be no surprise that these two countries have been losing production share since the turn of the century.

[12] There are some exceptions, although other product attributes appear to be more important than origin (Uchida et al., 2014; Roheim et al., 2018)

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