

# Essays in Aquaculture Economics and Marketing

by

Arne Sørvig

Thesis submitted in fulfillment of  
the requirements for the degree of  
PHILOSOPHIAE DOCTOR  
(PhD)



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University of  
Stavanger

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ESSAYS IN AQUACULTURE ECONOMICS AND MARKETING

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## Preface

This thesis is submitted in fulfillment of the requirements of the degree of Philosophiae Doctor (PhD) at the University of Stavanger, Faculty of Science and Technology, Norway. The research presented has been carried out at the University of Stavanger in the period of October 2011 to October 2014, and at BI Norwegian Business School, Department of Strategy, Oslo from March 2012 to June 2013.

I am grateful to my main advisor Associate Professor Roy Endre Dahl and co-advisor Professor Ragnar Tveterås for their careful guiding. I also owe a special thanks for support and research collaboration to Professors Frank Asche, Håvard Hansen, Yuko Onozaka and Kristin Roll. Thank you also to fellow PhD students, in particular Hilde N. Sandvold and postdoc Dengjung Zhang for research collaboration.

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There are so many to thank for the inspiration that took me in this direction. With more than 20 years of experience in the field of leadership, development and marketing in food and food related industries, so many encounters have provided insight and inspired the necessary curiosity for this thesis. I thank you all. If you read this you know who you are.

Finally, to family and friends that have had to experience at first hand this somewhat selfish venture: Thank you for the support!

Stavanger, November 2015

Arne Sørvig



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**PART 1: AQUACULTURE, DOWNSTREAM MARKET  
CHANNELS, SUPPLY CHAINS AND TRANSACTION COST  
CONSIDERATIONS**



## **1.0 Introduction**

### **1.1. The entrepreneurial revolution in aquaculture**

The global aquaculture sector is currently experiencing a market revolution. In 2003, the Economist described the evolution of aquaculture during the 1960 and -70ies as a Blue Revolution. Many key scientific breakthroughs and innovations allowing for human control of fish biology and breeding happened during these decades. The breakthroughs created a number of new opportunities, and the knowledge foundation for industrial aquaculture. However, the main market impact due to the so called blue revolution did not start until the 1990ies (Figure 1.1), and is accompanied by a revolution in seafood supply chain organization, as the control with production in aquaculture also allow for new forms of logistics, transports, sales and marketing. The aquaculture revolution is still ongoing, spinning off innovations in industrial production and distribution, ownership integration,

management and business models, thus creating a dynamic sector with global scope. This thesis' address key economic and marketing issues of this entrepreneurial revolution.

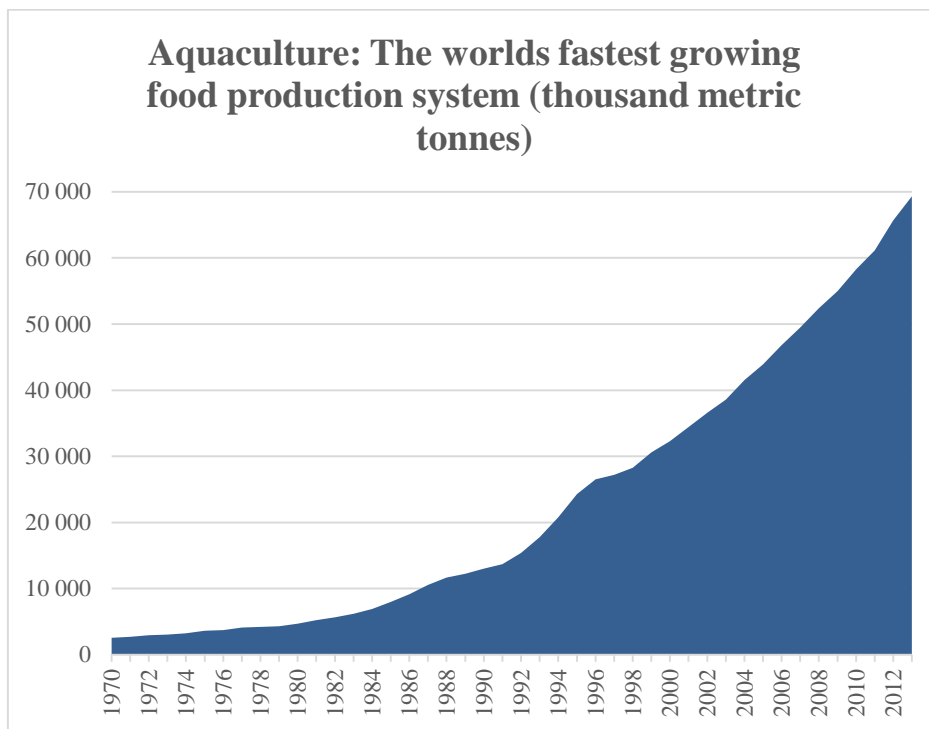


Figure 1.1. Exponential growth of global aquaculture production (source: FAO Fishstat Plus)

Aquaculture is the fastest growing food production technology worldwide (FAO, 2014), leading to increased food production

and economic opportunity. As wild capture fisheries seem to have stagnated, the only solution to maintain the per capita seafood consumption is through aquaculture. In 2014, the output from aquaculture surpassed that of wild capture as seafood for human consumption, tipping the volume balance towards aquaculture. Never before has the global per capita seafood consumption been higher, and never before has the world experienced higher levels of trade with seafood than today. These are both effects of aquaculture growth (Asche, 2008; Tveteraas et al. 2012; Asche et al, 2015). The Economist (2003) emphasize aquaculture's '*promise to alleviate poverty and food shortages, and if ... well done, safeguard marine resources for future generations*' (Economist, 2003). Aquaculture is overall a success story. Yet it is a history plentiful of associated negative issues, in particular related to the environmental impact of the industry. The focal orientation

of this thesis is economic and market issues. However, environmental sustainability issues are inherently part of economic outcomes of aquaculture (Smith et al., 2010), and are therefore included as a factor affecting economy and marketing. The World Bank (World Bank Report, 2013), summarizes this relationship in the following advice:

*“Demand is growing rapidly... This is a great opportunity for States that manages their resources well and understand the global marketplace. However those States that do not urgently move to sustainable management systems could face disastrous outcome for their oceans and their people”.*

## **1.2. Industrial salmon aquaculture**

Within global aquaculture, the departing reference for this thesis is industrialized aquaculture in general, salmon aquaculture in particular, and the economic issues are related to growth and innovation at the core. The industrial technology-driven *for-business-aquaculture*, like the Atlantic



Salmon industry, are characterized by biological control (i.e. systematic breeding), high-value products and wide reaching global supply chains supporting large scale production input and output. Traditional *for-food-aquaculture* is low-tech, dependent on local resources, produce for very local consumption and is often integrated as an additional activity to other terrestrial production (Sorgeloos, 2013). The output of traditional systems however is significant. China alone produces close to 15 million metric tonnes of seafood from traditional small scale systems (Ibid, 2013). In relation to production from salmon aquaculture, this volume is more than seven times the volume of Atlantic salmon. The economic value from traditional systems is significant, and it would be realistic to expect that entrepreneurs that are attracted by the opportunities will invent methods to develop larger-scale industrial structures with the economic principles of growth,

management and innovation. Any closer analysis of *for-food-aquaculture* systems, however, is out of the scope of this thesis.

With the expansion of industrial aquaculture a series of technology innovation in breeding, feeding, slaughtering, handling, packaging and distribution has followed (i.e. Asche et al. 2013). Yet, global aquaculture is a heterogeneous sector where problems and solutions are local, related to the individual species, the aquatic site and environment, the selected cultivation systems and the countries in which the activity takes place. Still, it should be possible to identify common parameters that can explain growth, or lack of growth. We assume that governing institutions, private and public, play a significant role in aquaculture development, but this assumption is challenging to investigate for several

reasons, including heterogeneity of, or simply lack of specific comparable institutional parameters.

### **1.3. Increasing value creation in markets and consumer products**

The heterogeneity of the aquaculture sector, status of development and challenges on a sectorial level have been discussed in several articles over the last decades (i.e. Andersson, 2002; Asche, 2008; Bostock et al. 2010; Sorgeloos, 2013). A common orientation in these papers is towards biology, environment, technology, production and supply chains, thus an upstream perspective. Such summative articles build on the relatively large body of research related to the upstream, or supply side of aquaculture. The main sources of financial risk and rents in aquaculture are located within the interactions between biology, natural environments and operative decision-making (Asche et al., 2009; Tveterås,

1999). The primary challenge has been to produce efficiently with stable quality, increase productivity and gain competitiveness in international markets (Asche et al. 2013; Asche and Guttormsen, 2009; Kvaløy and Tveterås, 2007). Therefor market research has primarily been associated with economic market demand, market integration and market power studies. However, over the last 10-15 years a body of seafood specific research that moves downstream to include industrial buyers and consumers is developing (Bjørklund et al. 2010). This seems to follow the Norwegian salmon industry as it evolve deeper into its markets through increasingly sophisticated vertical coordination, secondary processing and product innovations (Tveterås and Kvaløy, 2006; Kinnucan and Myrland, 2007; Dekeyzer, 2010).

Atlantic salmon initially traded in traditional market channels. Over time, different production characteristics compared to

wild fish, in particular a higher degree of biological control, allowed salmon producers and professional buyers in retail and food industry to interact directly. Direct market channels have decreased the use of intermediate actors in the traditional channels, like wholesalers and distributors. The stability of the direct supply chains has allowed for a large-scale product development and processing of fresh seafood consumer products previously unknown to seafood supply chains, leading to significant demand growth (e.g. Asche et al. 2011).

Figure 1.2 describes productivity, price and volume development in the Norwegian salmon industry (Asche et al. 2013). Production cost flattened from year 2000, and is currently rising due to biological challenges (e.g. sea lice). In the same timeframe from mid-1990s price, despite volatility, shows relative stability given the strong production growth in the same period. The price achievement implies that supply

grew with demand, or demand grew with supply, maintaining a balanced market.

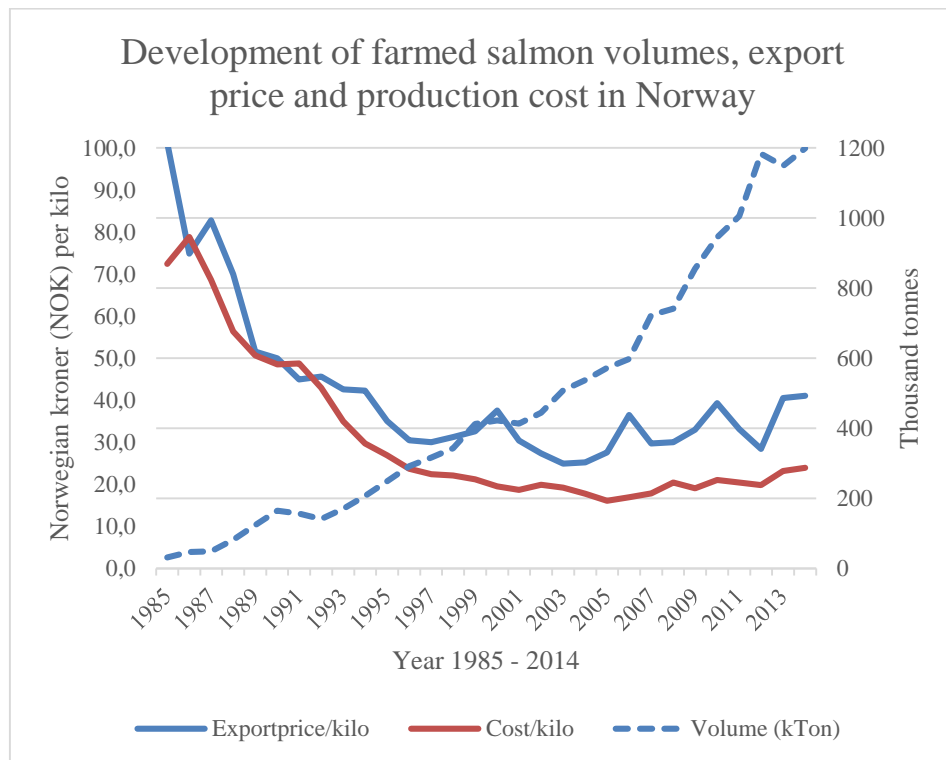


Figure 1.2: Development of export price, costs and production volume in salmon aquaculture in Norway (Source: Norwegian Directorate of Fisheries, 2015)<sup>1</sup>

<sup>1</sup> This graph was first presented by Professor Frank Asche in "Trade Disputes and Productivity Gains: The Curse of Farmed Salmon Production," *Marine Resource Economics*, 12 (1997), 67-73.

During the same period (year 2000 onward), the number of buyer-countries for Norwegian salmon has decreased (Figure 1.3). Hence, demand growth did not happen through adding new country-markets, but through increasing household penetration and frequency of consumption in established markets.

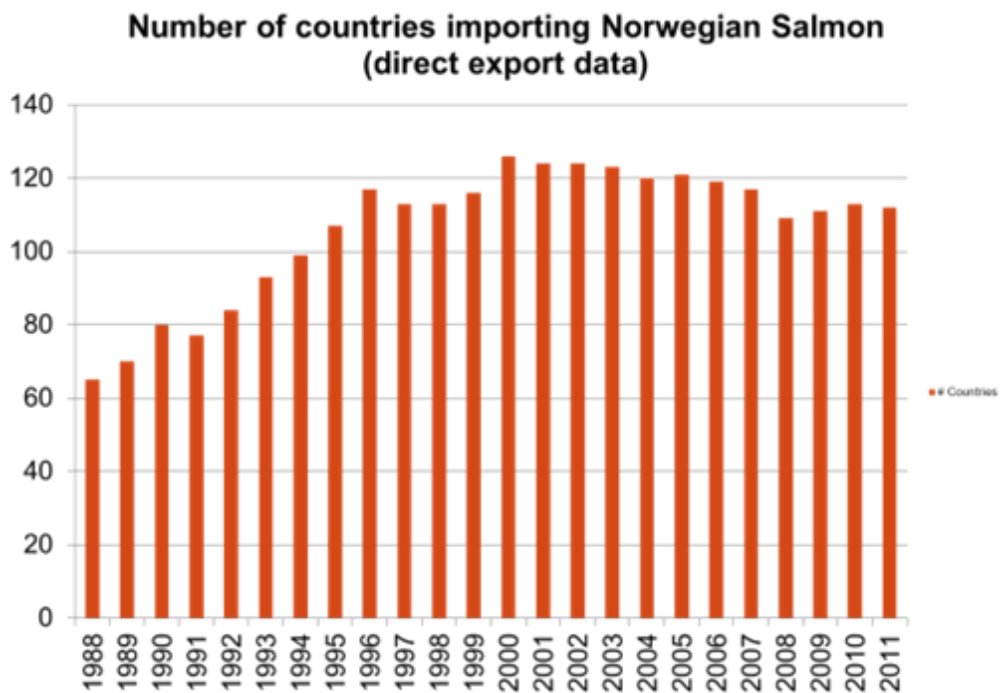


Figure 1.3: Number of countries importing salmon direct from Norway 1988-2011 (Source: NSEC, 2013)

The production increase is attributed to productivity growth, supply chain efficiency and increased demand (i.e. Tveterås and Kvaløy, 2006; Asche et al., 2011). However, while demand studies have investigated economic factors like price, income, and effects of marketing (Onazaka et al. 2014), there are few papers about how issues like modern grocery retail and food industry consolidation, product development, changing consumer preferences, choice and behavior impact value of salmon on an aggregated level. The article about consumer heterogeneity as source of differentiation and demand intends to understand why consumers behave differently despite the relative homogeneity and generic characteristics of the products. This thesis also includes a paper about supplier-buyer relationships duration in the salmon supply chains, and thus studies business-to-business marketing issues. From the point of harvest and onwards one would expect that the supply



chain and market dynamics would be similar for fisheries and aquaculture. That is not the case, and some of the issues that differentiate salmon from other farmed or wild seafood species are analyzed through the lenses of transaction cost economics.

#### **1.4. Summary of the four papers on aquaculture economics and marketing included in this thesis**

##### **1.4.1. Salmon Aquaculture: Larger Companies and Increased Production**

With Asche, F., K. H. Roll, H. N. Sandvold, A. Sørvig and D. Zhang.

Published in *Aquaculture Economics and Management*.  
17(3): 322-339.

Measured by production growth salmon is among the most successful aquaculture species. With production growth from 12 thousand tons in 1980 to over 2.4 million tons in 2011, production has increased faster than total aquaculture production, indicating an even faster innovation rate and productivity growth than for aquaculture in general. Productivity growth is associated with improved input factors,

better farm practices, improved logistics and more efficient supply chains, as well as increased scale (Asche, 2008). Two factors in production growth, development of farm size and company size, are studied closer in this article. Company size is relevant through development of economies of scale in production. It is also potentially important indirectly through expected higher capacity to develop technology, products and market, collaborate with large factor input companies like feed producers, to carry stricter regulatory measures due to externality risks, develop instruments to manage financial risk, as well as managing communication and institutional relations on a global level.

Several studies have investigated productivity growth and scale economies at the farm level. Less attention has been given to farm-holding company size, primarily because data at this level is hard to come by. Still, several companies have grown large through both organic and structured growth, through either horizontal or vertical modes of integration, or combinations of the two. The available data is too scarce for traditional productivity analysis accounting for firm structure. However, through different data it has been possible to shed

light on the issues. The article shows how the average farm size has developed in Norway, and measure concentration in the production in the five leading salmon regions of the world. In Norway findings suggest a substantial intensification over the last 30 years. Also, in all regions company size and industry concentration has increased. We find that the current concentration level in the global salmon industry is low. With a global market for salmon, there is accordingly little reason for concerns with respect to the competitiveness of the industry under the current conditions.

#### **1.4.2. In it for the Long Run: Supplier-buyer relationship duration in fresh farmed salmon supply chains**

With Ragnar Tveteras. *Unpublished per datum.*

This paper is about commoditization and industrial supplier-buyer relationships in the current salmon supply chain. It lends key concepts from Williamsonian transaction costs economics theory to explain observed forms of vertical coordination modes and governance forms.

In a few decades, salmon farming has evolved into a significant global food production system. Initially, produced salmon volumes was sold in the traditional wet-fish market channels, competing on price and basic quality parameters like other fish commodities. Despite supply growth and stability that have enabled establishment of direct supply chains to large customers, the salmon industry is still portrayed as a highly commoditized spot price driven industry. Hence, one would expect to find relatively uncommitted customer relationships in the industry's market channels. Commodity spot markets are governed by price, associated with auction-style discrete transactions with little relational commitment between transactions.

Salmon trading is however increasingly becoming large account specialist sales. The volume growth on both supply and demand sides have also lead to larger transactions. Annual inter-firm transaction volumes of five thousand tons and more are common today. Thus, annual contract transactions take on significant economic value. Envisioning that such significant flow of goods is organized through discrete spot market deals where the second transaction is independent of the first is difficult, even unrealistic. Therefore, it is expected that that an

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open spot market is replaced by another form of market coordination authority involving enduring business relationships (i.e. contract, trust and norms, bureaucracy). We find that farmed salmon trade is commoditized but not highly so. Findings indicate preferences, stability and structures that characterize departures from pure spot markets in which commodities often trade. Stable supplier-buyers relationships seem to be the norm.

### **1.4.3. Growth and Innovation in Marine Aquaculture: More species, Slowing growth**

With Ragnar Tveteras. *Unpublished per datum.*

The Food and Agriculture Organization of the United Nations (FAO) and others expect Aquaculture to be a major source of food protein resource to a growing global population. However, there are concerns about constraints facing aquaculture, the lack of research and development into improving productivity and sustainability, and the effects on future growth. Global aquaculture in general and marine aquaculture in particular is still growing rapidly. But growth rates during the decade 2000-2010 were lower than preceding decades. Given the necessity of aquaculture to grow in order to meet food security targets, a slower growth rate should be an issue of concern. We find that growth of aquaculture has been associated with entry of both new species and countries. However, we also find that a limited number of species and countries continue to dominate marine aquaculture, and that the top species four decades ago still are among the leading species today. So, despite a relative high degree of innovation with new species the majority of output volumes stem from

established species. We find that many sectors have failed to grow, and instead have stagnated and declined, and discuss factors that influence growth, such as innovation, externalities and external returns to scale. Results from analysis suggest that growth rates of aquaculture sectors in general and marine sectors in particular may be related to both external economies of scale and learning effects.

#### **1.4.4. Consumer Product Perceptions and Salmon Consumption Frequency**

With Onozaka, Y. and H. Hansen. Published in *Marine Resources Economics*, Vol. 29 (4)

Food consumption decisions are complex, as they are affected by various personal values and ideals, real-life constraints, as well as social and cultural dynamics. Since consumers are different in these aspects, food choices are inherently heterogeneous. Understanding consumer heterogeneity is a central issue when estimating and forecasting market demand for various goods and services, and designing marketing strategies. In consumer research, accounting for the

underlying heterogeneity is fundamental to better understand consumer' market behavior. This paper provides insights by applying the general framework of food related lifestyle (FRL) in an investigation of the relationship between product perceptions and consumption frequency for salmon. Seafood consumers are vastly heterogeneous in terms of their knowledge levels, confidence and perceptions about seafood. The relationship between consumer perceptions and salmon consumption frequencies is examined, while modeling the unobserved consumer heterogeneity by segmenting consumers based on their food related lifestyle.

We find significantly different salmon consumption frequencies and varying marginal effects from specific product perceptions among food-lifestyle segments. This indicates existence of general cognitive values which influence specific behavior such as consumption frequency of salmon. Such insight shed light on consumer issues that on aggregated levels might be important to understand how consumer preferences and behavior affect demand and pricing sensitivity.



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A latent class analysis that embeds the structural equation modeling is employed to ensure that the latent nature of both the consumer segment and the food lifestyle measures are properly accounted. Co-author Yuko Onazaka is a specialist on this type of econometrics and ran the analysis.



## **2.0. Salmon downstream market channels and supply chains and transaction costs**

Over the last two decades technologies and the organization of farmed salmon processing, distribution and marketing have undergone significant changes. This has among the many changes lead to a development of many new salmon products and new direct market channels. Hence, current farmed salmon distribution represents a radical departure from the traditional fisheries market channels/supply chains involving a multitude of independent brokers, distributors and wet-fish spot markets intermediating between upstream production and final *customers* (retail, food service and food service). In this chapter business-to-business market channels for salmon are briefly described, followed by the theoretical rationale for applying a transaction cost economics framework in analyzing market channel issues.

## 2.1. Marketing channels

A producer must create at least one path of distribution to access its potential buyer, convert that prospect into a customer and fulfill the customer's orders. A share as significant as 30-50% of the retail dollar in many US industries are collectively earned by channel members (Stern and Weitz, 1997), emphasizing the economic importance of market channels and the scope of activities and transactions (Chopra and Meindl, 2003). A substantial part of a marketing channels' role is to transform prospects' to profits, hence channels do not only serve markets, but also *make* markets. According to Anderson and Coughlan (2002), a market channel perform eight major functions: take title (ownership), take possession (stewardship), promotion, negotiation, financing, taking risk, ordering and payment. The accrued advantage from good channel management is strategic,

because it is often durable, difficult to put into place (entry barriers), and difficult to imitate (Stern and Weitz, 1997).

Ness and Haugland (2000) noted that retailers compete vertically upstream to achieve correct products in sufficient volumes, while salmon producers compete to achieve optimal market access. Prices are determined by supply and demand conditions, and the parties normally operate with an agreed spot market reference price (e.g. NOS, Urner Barry), when transactions are not in the spot market. Salmon, unlike most landbased livestock proteins (i.e. chicken), have limits to production growth due to natural and regulatory conditions (access to functional sites, operating license, sustainability). There is still a degree of seasonality in production (due to e.g. seawater temperature) as well as in demand (e.g. Christmas, Easter). Salmon farming is also subject to a degree of random variation in size and quality that become visible upon harvest.

In addition, salmon production time is up to 30 months, compared to a few weeks for chicken. Hence, capital requirements and risks are far higher for salmon, creating a series of pressures on downstream coordination. Efficient supply chains are fundamental to the profitability of salmon farming, as it is for the quality of the consumer products at the end of the market channels.

### **2.1.1. Salmon industry products and market channels**

In 2013, global farmed Atlantic salmon production was 2.3 million tons wfe (source: Kontali, 2014). Norway's total production reached 1.17 million tons (WFE), up from 12 thousand tons in 1980. 67% of the 2013 total Norwegian volume was produced by the ten largest producers, in 1998 the share was 24% (Directorate of Fisheries, 2014), an industry consolidation that is described as moderate by Asche et al. (2013).

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The relationships between main products and marketing channels in the salmon industry are simplistically summarized in a salmon product channel matrix (Table 2.1).

Product form	Temperature			Market Channel			
	Fresh (bulk)	Frozen	Chilled	(*) Retail	(*) Food service	* Food industry	* Wholesale (distr.)
Whole gutted <sup>^</sup>	X	(x)		(*)	(*)	* Food industry	* Wholesale (distr.)
Filleted <sup>^</sup>	X	(x)	(x)	(*)	*	*	*
Portioned pack <sup>+</sup>	(x)	X	X	*			
Smoked pack <sup>+</sup>		X	X	*	*		
Marinated pack <sup>+</sup>		X	X	*	*		
Coated/precooked <sup>+</sup>		X	(x)	*	*		
Further (Sushi etc) <sup>+</sup>	X		(x)	*	*		

<sup>^</sup>Primary processing/raw materials. <sup>+</sup>Secondary processing. ( ) = to a lesser degree

Table 2.1: General salmon product channel matrix (illustration by author)

Salmon farming and primary processing are highly automated and to a large degree vertically integrated activities (Kvaløy and Tveterås, 2008). Fresh raw materials are input factors for



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secondary processing and bulk retailing. The more elaborated a salmon product (high value add) is the less automated is the processing: A raw MAP salmon portion of 125 grams can be cut and packed with high automation, while a salmon roll filled with herbs and lobster require high degrees of manual labor. The matrix is, however, a coarse construct and serve its purpose just to illustrate 1) levels of elaboration, 2) types of temperatures and 3) main market channel and the products traded. For instance, food industry purchase raw materials, processes it and trade all types of elaborated products and could be marked with an X on all products. The complexity of interdependent trade and processing interactions reflects reality. Distribution takes place amongst a network of raw-material suppliers, processors, retailers and customers (Anderson, Håkansson, and Johanson, 1994).

A whole array of secondary processing- and packaging technologies has been adapted to salmon and other seafood species. Modified atmosphere packaging (MAP) prolongs significantly shelf life for fresh, smoked, marinated and other elaborated forms, incl. frozen. These packaging innovations expand current channels and open new market sub-channels for fresh seafood (e.g. chilled counters in convenience, and discount stores), thus multiplying eating occasion opportunities among consumers. According to Dekeyzer (2010) about 1367 new salmon product launches took place in 2008 and 2009, with close to 40% of them launched in the UK and France. For cod the similar data was 267 launches, while chicken launched 2724 new products. A similar picture emerges when conducting a Google search for recipes (Asche and Guttormsen, 2014). For chicken and cod, as for salmon, the most innovative European markets were UK and France.

Meatiness, taste, fat and color, combined with stable availability explain the relative success of salmon in consumer markets. In industrial channels, explanations are found also in additional attributes (i.e. uniformity, stability, quality, size-distribution, certifications and more).

Fresh head on gutted (HOG) and fresh fillet products are the main product forms leaving primary processing plants in country of origin. Market channels transform this raw material to consumer products through multiple activities. Today salmon end-consumers can access a wide variety of fresh, smoked and marinated convenient consumer products. Initially, in the farmed salmon industry's early years (1970-1990) it traded principally in the traditional wild fish wholesale commodity channels. Today the industry trade in direct retail channels and in highly specialized, capital-intensive value added processing supply chains. This channel

innovation and shift has differentiated salmon as seafood raw material and fresh retail product from other species in both the supply chains and among consumers. This is illustrated in figure 2.1.

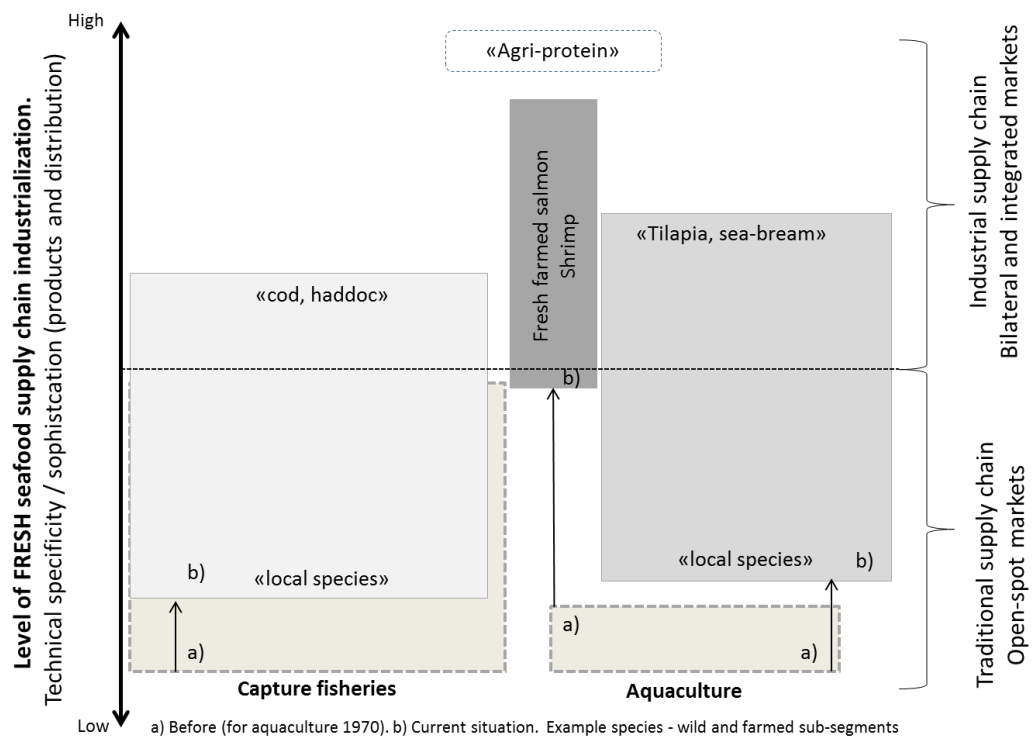


Figure 2.1: Seafood supply chain industrialization and salmon differentiation, capture fisheries vs. aquaculture (illustration by author)

## **2.2. Salmon Supply Chain Market Channels**

Salmon industry supply chains are among the most industrialized in the seafood industry (Asche and Bjørndal, 2011) and interact with four main industrial market channels: Retailers, Food Industry, Food Service and Distributor/Wholesalers/Traders. Figure 2.2 illustrates the vertical channel interfaces between the salmon producers and downstream markets channels. The sales and supply chain (SSC) links represent areas of transactions that require vertical coordination of some form. In the figure fragmented (lighter tone in the circles) and consolidated (darker tone) parts of each channel/sector are illustrated separately. The figure illustrates how salmon is mainly traded directly from salmon producers into the consolidated parts of each market channel (thick arrows), which from an industrial perspective make sense due to product characteristics and the increasingly consolidated farm production. Less consolidated parts of the channels are

traded mainly through intermediators (thin arrows from Distributors). Intermediators supply niche segments of each channel, such as specialty shops, independent restaurants etc.



\* Dotted circle indicate the firm boundaries of the salmon farmer not engaged in downstream secondary processing. (activities within include farming, harvesting, primary processing to head-on-gutted and raw material fillets) .SSC=Sales&SupplyChain. Consolidation refers to industrial structure in terms of large or small scale activity. Arrows indicate flow.

Figure 2.2. Salmon supply chains and customer interfaces (illustration by author)

### **2.2.1. The European seafood processing industry**

The European Fish Processor Association (AIPCE) estimates that the European seafood industry in 2013 represents more than 3975 firms, employing about 126.000 people (99.000 in companies of >20 employees) and generates a total annual value of €23billion. It is a fragmented industry. However, the firms in the salmon supply chain are increasingly accumulating activity in fewer firms through organic and structured growth. In particular salmon smokers and secondary processors involved in ready-to-eat MAP products, hereafter referred to as *fish-packers*, in mature salmon markets are growing in scale and scope. *Fish-packer* as a larger scale industry is a relatively new activity in a European perspective. This growing industrial activity of special interest as it is

bound to radically change market channels and salmon consumption.<sup>2</sup>

With this evolution of, and the rapid increase in range of fresh salmon products packed in modified atmosphere (MAP) a new era of sales and marketing of fresh salmon consumer products has started (Ortega-Rivas, 2009). By establishing supply chains with unbroken low temperatures from farm to the supermarket's chilled counter, improving hygiene practices in processing plants and applying MAP technologies, fresh salmon products shelf-life can be increased significantly (Ortega-Rivas, 2009; Sivertsvik et al., 2002). Seafood mature markets in Europe are experiencing a significant shift in how fish products are purchased and consumed at the consumer level, which impacts supply chains and practices in both fish

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<sup>2</sup> And as salmon is a leading species in the development of many new market channels, this process is likely to change the market channels for other seafood products.



farming and capture fisheries sectors. Fish is being moved out of wet market channels, like the traditional fish-monger area, and into the chilled products self-service counters. This development is similar to what has happened to agricultural proteins when meatpackers grew and consolidated with increasingly sophisticated packaging technology and supply chains.

*Fish-Packers* supply retailers with the day-to-day chilled fish-counter offer. They also supply other segments (e.g. food service operators). Retailers increasingly depend on fish-packers to offer product variety. In-store product-variety is based on multiple products from the main species (e.g. salmon, shrimp, cod) and a wider selection (scope) of species (e.g. seabass, tilapia, haddock, sole, lobster). The possible combinations create a relatively complex operations, requiring

specific procurement and supply chain capabilities that can handle this complexity on a daily basis.

Some *fish-packers* coordinate activities with retailer-customers through long-term bilateral arrangements (e.g. NorgesGruppen/Lerøy, Tesco/Seachill), semi-integrated through joint-ownership (e.g. Mercadona/Caladero), integrated through retailers ownership (e.g. Intermaché, Morrisons), while others retailers purchase their MAP-product range in the market with independent *FishPackers* (e.g. Salmar's, Norway, Marine Harvest VAP-plants). Finally, others purchase raw materials directly upstream, and contract fish-packer single species processing capacity on a cost-plus arrangement of 1-3 years duration. In the latter retailers take less ownership in the actual processing and thus coordinate the fish-packing activity as a market transaction. Figure 2.3 illustrates observed vertical coordination forms.

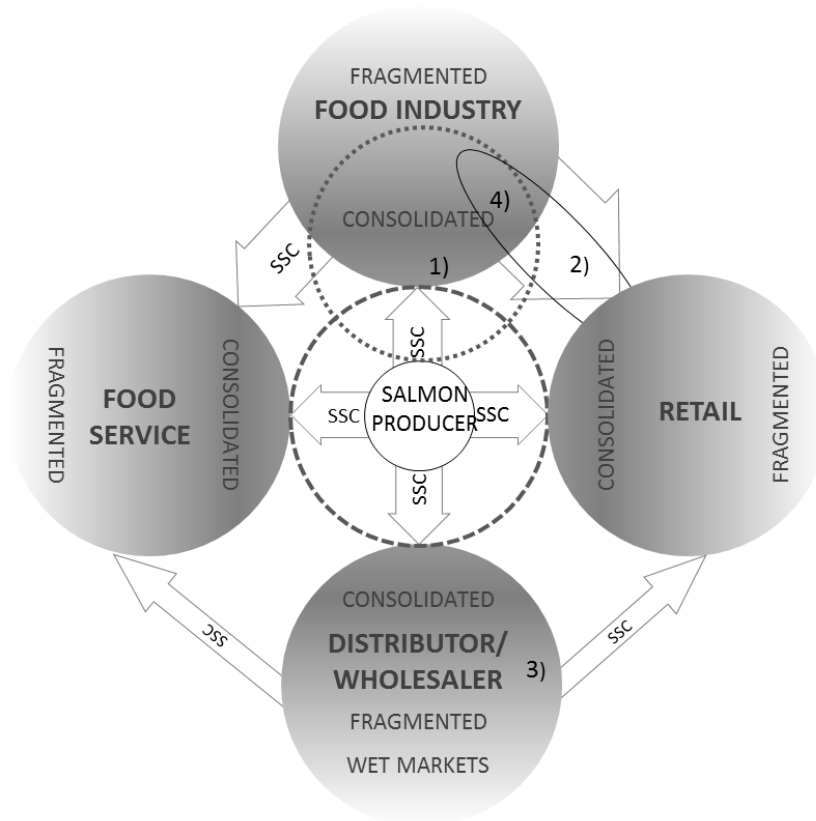


FIGURE: FISH PACKER DYNAMICS (Sorvig, 2014)

- 1) Salmon producers integrate forward to fresh fish-packer activities (is happening in Europe, US and Asia)
- 2) Retailers integrate backward to fresh fish-packer activities (is happening in Europe)
- 3) Distributors add processing activities (fishpacking) to own supply chain (common in the US)
- 4) Potential area for joint-venture, alliances between salmon producers and retailers?

Figure 2.3. Governance modes for fish-packer activity (illustration by author)

In most modern European markets where chilled MAP seafood is growing, fresh salmon is the most sold seafood

species (category captain) in terms of both turn-over volume and product innovation (Dekeyzer, 2010). In principle, *fish-packers* perform the outsourced activities previously performed by the retailers' own internal fishmonger, just at a far larger scale but also with a lesser scope in number of species<sup>3</sup>.

In 2012 the European *salmon smoker sector* produced 160.000 tons product weight (eqv. 310,000 tons live weight). Operations have reached considerable scale and distribution scope, with regional and international reach with chilled and frozen products (e.g. Morpol, Suempol). 60% of the European volume is now produced by the ten largest processors (Marine Harvest Industry Handbook, 2013). Returns to scale define the

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<sup>3</sup> A visit to an Auchan or Carrefour-store in Paris, or a Mercadona in Valencia would illustrate operations.

productivity and price competitiveness, creating a race towards becoming the lowest cost producer. Not to many years ago smoked salmon was regarded as differentiated products by the local and national processors spread throughout Europe. This has radically changed over the last decade.

### **2.2.2. Food service**

*Food service* sales in Germany, Italy, France, Spain and UK in 2012 were estimated to €278bn. Industry concentration in chains increases in all countries with UK and France as the most consolidated (58% and 45% under retail banners/chains) and Germany, Spain and Italy the least concentrated (<27%). Less than 1% of total registered servings were fish (NPD Group, 2012). Food service represents all out-of-home meals eaten, including catering, institutions and in some cases convenience stores. There are few direct deliveries of raw

material salmon between salmon producers and food service operators. The large operators demand portions and ready-to-cook or -eat products (latter are usually frozen), while small operators trade at local wet-markets or with specialized distributors.

### ***2.2.3. Modern Grocery Retailing***

*The grocery retailing sector* in developed countries has experienced significant changes of power shifts over the last four decades. First manufacturers held the upper hand, then it was transferred to retailers and finally to consumers (Messinger and Narasimhan, 1995). The top five grocers in the US held 31% of the grocery market in 2011. In France the Top5 held 71% of the grocery market in 2013, in Germany it was 82% and in the UK 70% (Planet Retail, 2014).

There may be a relationship between grocery retailing concentration and salmon sales. Salmon has been growing with modern grocery retailers in most markets, which suggest that there is a ‘structural fit’ in the supplier-buyer relationship. Salmon has a relatively uniform quality and size, stable supply and is easy to transform into fresh consumer products in popular demand. These characteristics fit with modern retail’s procurement and logistics systems. Traded volumes of salmon on central wet-markets in Spain and France have stagnated, while the total imports (mainly domestic consumption) of salmon have increased significantly during the period. Such change in trading patterns from labor intensive intermediate channels like wet-markets to direct supply chains is also described by Abrahamsen and Håkansson (2012).

### **2.3. Vertical coordination in supply chains**

Supply chains are composed of interdependent organizations assisting in creating economic transactions (Anderson and Coughlan, 2002). Key governance issues are vertical coordination decisions, channel relationship management, use of relational norms, and use of power (Jap and Weitz, 1995). Supply chain management is “*the coordination of production, inventory, location and transportation among the participants to achieve the best mix of responsiveness and efficiency for the markets being served*” (Hugos, 2011).

Huemer (2006) distinguishes between two interpretative perspectives of supply chains: (1) The efficiency-based, flow-oriented (cost) perspective, where flow is handled by a collective of actors sharing a desire to develop efficient networks (power-issues have no role in this perspective) and (2) the supply chains as strategic web of networks and value-constellations. The chain is interpreted as interaction, learning,



knowledge sharing and innovation. Value creation in this strategic web depends to a large extent on the business model of the (most powerful) strategic channel leaders. The two interpretations facilitate an understanding of Transaction Cost Economics (TCE). TCE is a governance perspective concerned with coordination and alignment similar to the supply chain interpretation as the efficiency, flow and cost orientation. The classical business strategy perspective involving competitive forces, value-chain and industry analysis, market power, positioning issues, resources and capabilities (e.g. Porter, 1980; 1985; Wernerfeldt, 1984; 1995) is closer to Huemers interpretation of supply chains as a strategic web of networks and constellations. To TCE strategic ploys and positioning is of second order of importance, as *“clever gambits will rarely save a firm in which serious governance misalignments are observed”* (Williamson, 1998).

Still, TCE has a significant role to play in strategic management (Foss, 2003, John and Reve, 2010).

A fundamental question in strategic management is how to achieve and sustain competitive advantage (Teece et al. 1996).

Alignment of supply chain management and business strategy is a continuous task of adaptation of and to customer needs, core competencies, the role the firm wish to play to serve its customers and the development of capabilities to support the chosen roles in the value chains (Hugos, 2011). Intangible assets like know-how, relationships, capabilities and business models influence firms' vertical performance (Teece, 2010).

#### **2.4. Transaction Cost Economics and Vertical Governance Modes**

Transaction Cost Economics describes a firm (hierarchy) as a governance structure, not as a production function. Alternative governance structures to firms (hierarchy) are open markets

and different forms of contracts (hybrids). The boundaries of the firm are defined by its core technology (Reve, 1990; Thompson, 1967), e.g. salmon processing, and related up- or downstream activities. Commons (1932) define governance as the means by which *order* is accomplished in a relation in which potential *conflict* threaten to upset opportunities to realize *mutual* gains. Commons consider transactions as the ultimate units of activity in economic organization, containing the three principles of conflict, mutuality and order. Transactions occur when goods or services is transferred across a technologically separable interface (e.g. fresh filleted salmon transferred to smoking operation).

Transactions can be governed in three distinguishable modes: Open-market, contracting (bi- or tri-lateral) or unified coordination (Williamson, 1998; John and Reve, 2010). According to TCE the coordination mode is defined by the

impact of transaction costs in each transaction: When the cost of buying a good in the market is higher than making it, the activity will be internalized or governed by contracts. And vice versa; if the cost of making it is higher than buying it, the activity will be outsourced. These are core assumptions in transaction cost economics (Williamson, 1975, 1979, 2010; Rindfleisch and Heide, 1997). The independent variables that influence coordination (governance) mode are Asset specificity, Uncertainty and Transaction Frequency (Williamson, 1979; John and Reve, 2010). The relationship between transaction costs and the independent variables can be illustrated by the following case: When an asset is highly specific to a buyer (high asset specificity), and transactions are characterized by uncertainty the acquirer would prefer to contract or integrate the asset (technology, production) in order to reduce risk.

Asset specificity takes a variety of forms, and is *'the big locomotive to which TCE owes much of its predictive content'* (Williamson, 1998). Transaction costs are the costs associated with planning, adapting and monitoring economic activity, or “the costs of running the system” (Arrow, 1969; Williamson, 1998). They must not be confused with production costs. Transaction costs are categorized into ex-ante costs associated with searching, drafting, negotiating and safeguarding transactions, and ex-post costs associated with policing and enforcing agreements, adapting to changes and measuring. When a transaction is agreed the transaction transforms from being located in a thick market (many competing players) into a thin market. Thin markets amplify the risks from specificity, e.g. thin market combined with high asset specificity will result in higher switching costs, hold up risk, and a stronger need for ex-ante safeguarding. TCE has predictive powers,

and is helpful in sorting out ex-ante or ex-post governance misalignments. Figure 2.4 is a simple contractual scheme that serve to illustrate the alignment reasoning, where asset specificity ( $k$ ) and safeguarding ( $s$ ) define choice of governance: Open market (A), Contract/Hybrid (C) and Vertical Integration (D). An intermediate Hazard (B) is included to illustrate the risky option (Williamson, 1998).

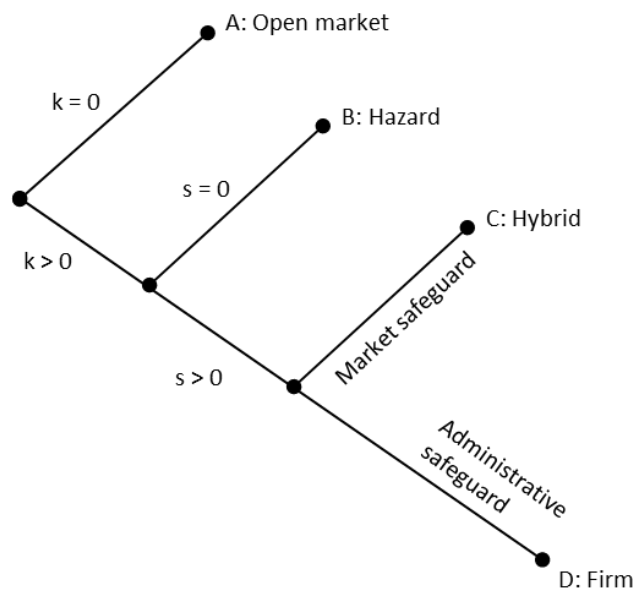


Figure 2.4. Simple contracting schema (adapted from Williamson, 1998)

In the first option asset specificity is low or non-existent ( $k=0$ ), for instance the product is a relatively abundant commodity. This transaction, or activity, should be coordinated in the open market. In the second option there are asset specificities ( $k>0$ ), which would require safeguarding against risk/hazards. If no safeguard (e.g. contract) is provided ( $s=0$ ), the transaction is hazardous. When safeguards are provided ( $s>0$ ) the transaction is either brought to order through contract (C), or integrated into the firm (D). According to Williamson the option to integrate into hierarchical governance should be the last resort as the markets are superior coordinators of transactions. The three processes that influence mode choice that has survived numerous empirical tests (John and Reve, 2010) can be summarized into the S-A-M-model:

- **safeguard** against under-investment in at-risk assets
- promote **adaptation** to changing circumstances

- mitigate undersupply of activities that lack verifiable outcome **measures**

Asset specificity, or specific investments, is the strongest predictor of mode choice, with uncertainty relegated to second-order effects empirically. Adaptations has proven difficult to measure due to empirical measurement problems on dyadic level, while the third ‘*lack of verifiable measures*’ yields consistent and significant effects (John and Reve, 2010).

TCE has also evolved into a dominant theory of the firm in the strategy field “because transaction costs are essential aspects of processes of creating, capturing and protecting value” (Foss, 2003). It is also a dominating theory for explaining market channel evolution (John and Reve, 2010, Anderson and Coughlan, 2002). Figure 2.5. models the theoretical relationships between dependent and independent variables.



		Level of asset specificity		
		Low		High
Uncertainty and measurement problems	Low	Spot market transaction	Long-term contracting	Various alternatives
	High	Spot market transaction	Hybrid solutions (long-term contract, alliances)	Vertical integration

Figure 2.5: Vertical coordination modes options  
(Adapted from Williamson, 1985, 1991a)

In this paper, TCE is utilized as a framework to illuminate observed issues in the fresh salmon supply chain. The author has many years of experience in consumer- and industrial marketing of seafood in general and salmon in particular in international markets. Personal insights, combined with interviews and established research findings are structured through applying the TCE framework. A general claim among practitioners that farmed salmon business is highly commoditized is the main motivation for performing this analysis.

In the following chapters different asset specificities and the coordination modes in relation to salmon supply chains are discussed. In figure 2.6. vertical supplier-buyer relationships in seafood business and the focal relationships for this paper are illustrated.

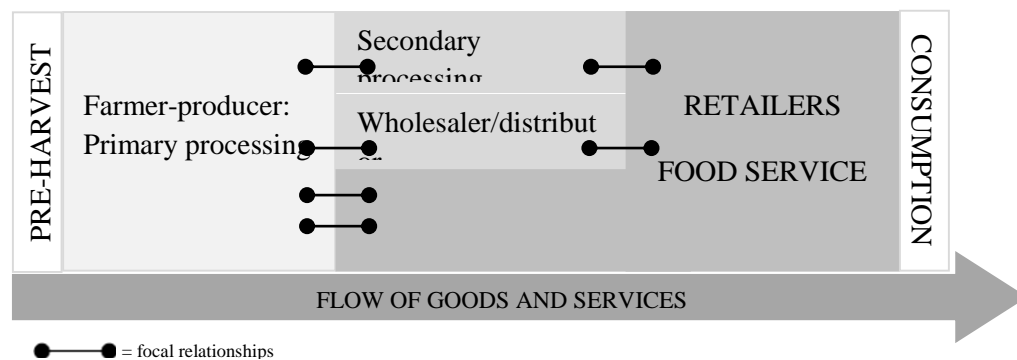


Figure 2.6. Salmon Industry vertical supplier-buyer relationships (illustration by author)

#### 2.4.1 Open market coordination and traditional seafood trade

In open market coordination mode, spot market price signals available supply, product quality and demand. In auction markets actors are more or less unrelated, and transactions

independent and discrete in the sense that a transaction neither follows the last, nor precondition the next. Issues of loyalty, personal relationship and other asset specificities play a lesser role in a commodity market. Buyers switch between suppliers depending on price, thus making price the authoritative coordination mechanism. Commodities are uniform, similar products normally produced in large volumes in qualities that are similar and interchangeable between suppliers. Hard and soft commodities are normally traded on virtual futures exchange markets, like the regulated market place Fishpool where future contracts are settled bilaterally or through a clearing house where buyers and sellers do not know about each other.

## 2.4.2. Contract coordination and salmon sales

As an alternative to spot markets trade, firms can write longer-term contracts. A well-functioning spot market allows agents to trade at competitive prices, but for farmed salmon open markets result in volatile prices, and may increase sales cost (Kvaløy og Tveterås, 2008). Contracts are primarily used to reduce risk and transaction costs, and have multiple designs. Channel complexity require contracting based on both formal content (clauses and their wording), or informal issues (relational governance). Some variables are listed below (adapted from Tveterås and Kvaløy, 2006; Anderson and Coughlan, 2002; Bradach and Eccles, 1989):

- The form of transfer pricing used (fixed price vs. other mechanism)
- Non-price aspect of the channel relationship
  - Contract timing vs. delivery (e.g. forward contracts)
  - Duration, one or multiple deliveries
  - Specification of production process issues (e.g. type of feed ingredients, specific quality procedures, third party certification of sustainability and animal welfare etc)
  - Specification of product attributes beyond production process issues (e.g. levels of Omega3, color etc)

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- Specification of quantities, including size distribution (e.g. total volume, purchase whole production or only specific sizes)
- Formal, bureaucratic structuring of the channel relationship
  - Supervision, authority allocation, centralization, formalization,
  - Procedures, rules, standards, sanctions
  - Vertical restraints and channel exclusivity
- Relational structuring of the channel relationship
  - Personal relations, role integrity, reciprocity, mutuality, flexibility, expectations
  - Accepting vulnerability, harmonization, preservation, adaption
  - Form of strategic leadership in the channel

In the TCE-framework contracting normally refers to long-term contracting on issues beyond price. Per definition a fixed-price contract only hedge against price volatility, and price remain the authoritative coordination mechanism like in any open spot market. Ness and Haugland (2000) distinguish between three types of long-term contracts: Classical long-term contracts, internal contracts and relational contracts. The differentiating feature between them is the ability to cope with uncertainty. In classical contracts the parties strive to write

complete contracts covering all possible outcomes, which TCE regards unrealistic due to *bounded rationality* (Simon, 1961). In internal contracts definitions of decision power, rules and formal routines govern transactions, often one-sidedly. The last type is relational contract, where long term mutual goals of the contract are emphasized along with intentions about relationship form (e.g. interactions, norms). This format allow for development of business relationship in transactions of high uncertainty. Trust governs the latter, normative contract type. Hierarchical authority governs internal contracts, and incentives govern the classical long-term contract.

### **2.4.3. Vertical integration**

In strategy literature, the rationality behind vertical integration decisions are not purely cost based. The entrepreneurial considerations about the configuration of activities and assets

in order to reach business targets involve both cost- and income-streams. Capturing and sustaining value is a key driver for reconfiguring value chains (Stabell and Fjeldstad, 1998). A main objective with strategy is to establish sustainable competitive advantages, and increase overall value creation (Christiansen and Fahey, 1984; Porter 1985). TCE offers a distinct governance perspective on the rationale of vertical integration. It is the least attractive coordination mode, and in Williamson's view only to be applied when the other modes fail to resolve conflicts and mutuality at lowest cost (see figure 2.7). Hence, according to TCE, vertical integration may lead to less optimal economic organization.

If salmon industry is a highly commoditized, one should – based on TCE-principles – observe less vertically integration than contract coordination, less contract coordination than open markets, and predominately a trade in open markets. This

seems not to be the case. In the farmed salmon supply chain one can observe vertical moves both downstream from salmon producers, and upstream from processors and traders. Thus, it is relevant to identify asset specificities that may motivate the different forms of integration.



**Relationships between asset specificity, transaction costs and modes of vertical coordination**

Firms that invest in specific assets have incentives to find alternatives to sales in an open market, to safeguard against opportunistic behavior from buyers or suppliers. In a contractual relationship one party can dedicate resources in specific assets to guarantee deliveries of certain volumes, while the other party can guarantee prices for agreed volume. The incentive to safeguard against opportunistic behavior increases with the magnitude of investments in the specific assets, and the investing party will for instance spend increasing amounts of resources on contractual specifications. However, complete contracts are difficult to write. Furthermore, contractual and legal loop-holes exist. This may lead to use of additional resources to investigate and police possible breaches to the contract. Vertical integration eliminates such problems, and is an increasingly attractive mode of coordination as the magnitude of specificity increases.

The figure below illustrates the relationship between asset specificity ( $k$ ), levels of transaction costs and coordination modes.  $SM(k)$  are transaction costs associated with spot markets, while  $CC(k)$  are transaction costs of contracts and  $VI(k)$  of vertical integration. When asset specificity is low ( $k < k_1$ ) transaction costs are lowest in spot markets. When specificity increases to  $k_1$  transaction costs are lowest in contractual modes, while transaction costs become lowest through vertical integration when level  $k_1$  is reached.

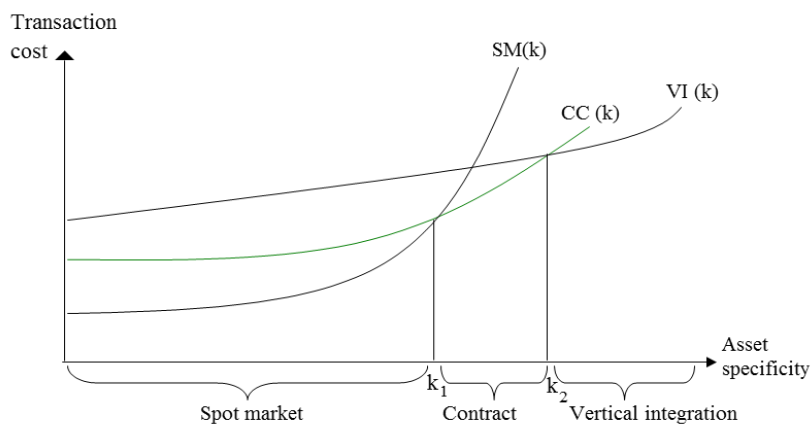


Figure 2.7. Degree of asset specificity, transaction cost and form of vertical integration (adapted from Martinez, 1999; Williamson 1991)

## 2.5. Asset specificity

Effects of specificity depends on the degree to which the assets involved are intended to use in a specific relationship, thereof the term specificity. When an asset with high degree of specificity is locked into an activity though a contract or integration, it can be re-deployed only at loss in productive value, which may result in sizeable quasi-rents<sup>4</sup>. The investing (risk-taking) partner can be subject to “hold-up”, or opportunistic (exploitative) behaviors by the other party and would want to safeguard against that. Due to specificity one of the parties, logically the less dependent, may generate above-normal rents at the expense of the other part. A decline in the numbers of buyers and sellers also lead to *small-number* bargaining problems and amplify real and perceived risk of hazards. A small number situation (thin-market) increases

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<sup>4</sup> Quasi-rent is the difference between the value of an asset in its best use and in its next-best use

potential for opportunistic behavior because alternative transaction partners cannot easily be reached. Hence, the asset is locked into a particular relationship, and the market for a re-deployment of a highly specific asset is limited (for instance, the asset could be a feedmill or large scale multispecies *fishpacker* plant). Thus, large switching costs for one or both partners, increase necessity to safeguard transaction through contracts or integration. By integrating the transaction into one of the partner firms, the conflicting specificity issues and imbalance is brought into alignment under hierarchical control.

Assets takes a variety of forms to which individuated governance structure responses accrue (Williamson, 1998). In this paper the specific asset-categories included are (1) physical, (2) temporal and (3) intangible assets (Teece, 2010).

They are discussed in relation to the salmon supply chain in the following sections.

### **2.5.1. Physical assets specificity, salmon products and processing**

Physical assets are physical items like machinery, buildings, production lines and products that are productive in certain uses, certain relationships or combinations of certain use and relationship. E.g. a fish-packer production line only has productive value when access to self-service counters is granted by the retailers. If the retailer can choose between several competing fish-packers, then the retailer can engage in opportunistic behavior and capture above-normal value by one-sided adaptation of the contract. The *fish-packer* would want a contract that safeguards against such behaviors ex-ante through contracting. On the other hand, continuing the case of the fish-packer; a large national retailer in a concentrated grocery market (e.g. UK) may not easily switch supplier (e.g. fish-packer market capacity may be tied up with competing retailers). In that case the *fish-packer* is a specific asset to the

retailer to assure right quality fish-counter all year round. If in addition the seafood sourcing capabilities are outsourced to fish-packers then the retailers' dependency would increase. How this asset specificity is safeguarded, and transactions are governed, is not clear. One will find all modes, from vertical integration of fish-packing (e.g. Intermarche [Fr.], Morrisons [UK], Mecedona[Sp.]), alliances (e.g. Norgesgruppen [No.]), exclusive longer-term contracts (Tesco [UK], Sainsbury [UK]), purchase of finished consumer products in open markets (e.g. from Salmar [No.], Marine Harvest [Fr., Be.]) or hiring capacity to process raw materials sourced by retailer (model found in Spain and France). In most mature markets, except the UK and France to a certain extent, retailers' ability to offer consumers a complete, balanced (multiple species, product forms) self-service fish counter is relatively new. It seems to be driven by packaging technology, consumer

demand and organizational and logistical entrepreneurship. The observed variance in governance modes signals that this is a business area that is still quite dynamic and unsettled.

Another example of physical asset specificity is when a processor depend on specific raw materials, due to specialization of its operations (e.g. investment in state-of-the-art processing and packaging technology). The need for vertical coordination increases through technologies that 1) have less tolerance for deviations in raw materials, and 2) require labor with higher specialization and education (intangible assets). Thus, physical asset specificity is expected to be drivers for vertical coordination in the fresh salmon supply chains.

Backward integration from secondary processing is rarely seen in the industry<sup>5</sup>. Among industry leaders this is explained

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<sup>5</sup> In the salmon industry history few backward vertical integration moves from customers have been seen. The polish smoker Morpol purchased farming operations in Scotland two years before it was acquired by

by the risk and capital intensity of salmon farming. Therefore one can expect when specificity is high that processors and retailers would, beyond contracting, have incentives to maintain efficient personal ties with the salmon producers as a source of day-to-day safeguarding mechanism.

### **2.5.2. Temporal specificity and need for speed from farm gate to table**

After harvesting and gutting, a salmon has a shelf-life of about 14 days when temperature control and hygienic conditions in the supply chain are adequate. Each day lost to non-sale reduce the value of the raw-material. Thus, there is a strong urgency in allocating the volume, in a profitable way. This urgency can be defined as temporal asset specificity.

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Marine Harvest in 2012. Apart from the Morpol-move, no significant backward integration from customers has been seen until 2014 when the Japanese seafood trader-house Mitsubishi acquired the Norwegian salmon producer Cermaq in \$1.4bn deal.



### **2.5.3. Human asset specificity**

Given that physical and temporal specificities exist, the accumulated know how and learning from recurrent transactions and interaction is expected to impact supplier-buyer relationship duration and governance mode. Repeated transactions develop specialized inter-relationship capabilities that lowers transaction costs. Transactions may be safeguarded by a shared requirement between buyer and supplier for proven collaboration, experience and trust. Transaction costs decrease and volume growth increase in buyer firms who are experienced distributors of salmon products at the consumer level, and a supplier that knows and is enabled to supply this buyers' specific needs for salmon may equally decrease costs and increase growth for the supplier. In the following such crucial capabilities are defined as human assets. Human assets can be regarded as specific to transactions. Human knowledge assets are generally costly to

transfer and can be difficult to specify in a contract (Teece, 1981), hence the identification of such rely on experience from transactions over time.

Specific firm and inter-firm insights are developed inside the firm, and within the supplier-buyer relationships. According to Levinthal and March, (1993) two major mechanisms facilitate organizational learning. The first is *simplification*, which minimizes interactions to the spatially and temporally neighborhood of the problem (e.g. salmon supply chain), and the second is *specialization*, where learning processes tend to focus attention and narrow competence (e.g. processing fresh consumer packs of salmon). By simplifying experience and specializing adaptive responses, learning improves organizational performance. However, the same mechanisms of learning that lead to improvements also limit a firm's problem-solving capacity. Levinthal and March note three

forms of learning myopia: The first form is a tendency to ignore the long run, the second a tendency to ignore the larger picture and the third a tendency to overlook failures. These myopic learning failures are embedded into a broader problem for adaptive intelligence, namely that organizations divide attention and resources between two kinds of activities; they engage in *exploration* and *exploitation*. Exploration is the pursuit of new knowledge, while exploitation is the use and development of things already known. Firms that exclusively engage in exploration will suffer from not gaining returns from its accumulated knowledge, while firms that engage exclusively in exploitation eventually become outdated (Levinthal and March, 1993). Simon, March and Cyert were among the first scholars to describe the important role of learning for organizational performance (Schulz, 2005).

In salmon farming profit flows from efficient management of natural resources, not from the fiords themselves. They flow to those who build privileged relationships with stakeholders, and develop safe, efficient and effective farming systems. Hence, profitability in salmon farming is a product of the “Minds” involved in operations and innovations, and not ‘Nature’. Customer relations, reputation, organizational culture, trademarks and patents are intangible assets that a firm may have more or less of, making it a potential partner for collaboration or target for acquisition. A salmon producers’ supply chain planning and sales activity is a good example of a highly specialized intangible asset.

Developing new know-how is not easy, and require investments in physical assets within which the know-how can be developed (they do not develop in a vacuum). To purchase the capability in the market is also complicated, because

specific knowledge is related to complementary assets (bundle) which may be both tangible and intangible assets. For instance, unless the physical assets to smoke salmon in real large scale, or upgrading production quality fish to premium quality products, are in place, the specialist competence to achieve this has less value. The same is true for sales competences. To bring in specialist retail key-account and category management competence into a department that primarily trade bulk raw material on a spot market may not change the firms' know-how and market approach (unless the specialist entry-position is influential). Hence, specialist competence requires products, operational systems and relations that fit the competence, if not the know-how will have less value. Therefor the third option, to integrate vertically might become the less costly, less risky and faster option.

Another intangible asset mentioned by Teece (2010) is the business model. The business model represents the entrepreneur's theory about the how a firm should compete in its market. There are different business models at work in the salmon industry. One large producer aim at becoming a fully integrated international protein company with a presumed generic consumer product extension (Marine Harvest Group), others focus tightly on national or international farming and primary processing with little or no downward integration beyond sales resources (e.g. Salmar, Cermaq), while others combine salmon farming with multispecies secondary processing and consumer product sales (e.g. Lerøy), and others differentiate on specific attributes and sell directly to specialist stores (e.g. Verlasso) and some focus intensively on efficient farming only (Alsaker Fjordbruk, Firda Sjøtroll). Within secondary processing and the relationship between

fishpackers and retailers there seem to be a variety of governance and business models at work, although the basics in operations should be quite similar (procurement, processing, logistics).

## **2.6. Uncertainty**

Uncertainty influence governance, and TCE establish relationships between asset specificity and uncertainty. For instance high specificity and high uncertainty transactions would normally be governed through vertical integrations (as illustrated in figure 2.5.). Uncertainty arises from three different sources (Williamson, 1985; 1996).

- 1) Technological changes, unpredictable changes in consumer preferences, and random acts ("bioshocks") from nature.
- 2) Insufficient information at the right time and right place, or an inability to determine and coordinate simultaneous decisions, plans and actions made by others, such as investment decisions and consumer purchasing plans.
- 3) Behavioral uncertainty: Strategic behavior regarding nondisclosure, disguise or distortions of information

Writing complete contracts with specifications of all possible events and outcomes is impossible or very costly. Actors have *bounded rationality* (Simon, 1961) because time and resources limits the amount of information that can be gathered and processed ex-ante (John and Reve, 2010). Monitoring performance and verifying breach of contracts also become more difficult as uncertainty increases. Ness and Haugland (2000) mention relational contracts as the contract form that best cope with uncertainty as it defines expected objectives and norms for cooperation rather than intending to safeguard against all possible outcomes. A relational contract is not a naïve contract building on a vague concept of trust, it is specified until the point where further specifications are not possible given constraints (time and resources). When asset



specificity is low, uncertainty it is expected to have little effect on choice of vertical coordination mode.

Bio-physical variations and even shocks occur, and are key sources of supply and price risk and uncertainty not only in farming but along the entire salmon supply chain (Asche et al. 2009; Tveteras, 1999). The demand side also represents sources of uncertainty affecting salmon prices, and even the profitability of the individual channel members (e.g. food safety issue under a specific supermarket banner).

Real and non-real issues related to food safety and ethics receives high stakeholder attention and represents threats to the integrity of raw materials, processors, consumer products and retail banners carrying the particular products in question. Consumer advocates and other stakeholders demand transparency and accountability from retailers and food producers about food safety and ethical issues. This demand

for information is often advocated through mass media, exerting strong pressures on the involved firms closest to the consumer.

Olson and Craddle (2008) observed that increasing demand for documentation represents a new competitive pressure in Chilean salmon industry, and that certification requirements are motives for vertical and horizontal integration. Relevant documentation requires very specific capabilities (human assets) in the supplier-buyer relationship. Information and certification is not a physical product issue, but a product of intangible assets related to a suppliers capability to maintain, gather and share relevant information<sup>6</sup>. Hence; a good supplier reduces buyers risk when for instance a food safety event gets real serious.

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<sup>6</sup> The annual reports of large producers like Cermaq, Lerøy, Salmar and Marine Harvest all agree about the strategic importance of quality control, assurance and documentation.

Uncertainty relates to measuring and measurement problems. For agriculture and aquaculture products measuring product attributes (color, meat texture, fat content) is a problem (Tveterås and Kvaløy, 2006), and may inhibit pure commodity trade due to insufficient measurement abilities. Information asymmetry between trading partners are also sources of transaction costs. For instance, when it is difficult to measure product attributes, but where volume and attributes of input factors signals final product attributes (e.g. feed ingredients), contracts allowing buyers to influence input factors may provide higher transaction efficiency.

Analyzing asset specificities and uncertainties in salmon trade within a Transaction Cost Economics perspective may be a relevant track to understanding the evolution of downstream seafood and salmon supply chains.

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## **PART 2. Papers included in this thesis**

Paper No. 1:

### **Salmon Aquaculture: Larger Companies and Increased Production\***

Co-authored with Frank Asche, Kristin H. Roll, Hilde N. Sandvold, Arne Sørvig and Dengjun Zhang, University of Stavanger

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Paper No. 2:

### **In it for the Long Run. Supplier-Buyer Relationships in the Fresh Farmed Salmon Supply Chain**

Co-authored with Professor Ragnar Tveteras, University of Stavanger

Not published

First author: Arne Sørvig

Paper No. 3:

**Growth and Innovation in Marine Aquaculture: Mores Species, Slowing Growth**

Co-authored with Professor Ragnar Tveteras, University of Stavanger

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First author: Arne Sørvig

Paper No. 4:

**Consumer Product Perception and Salmon Consumption Frequency: The Role of Heterogeneity Based on Food Lifestyle Segments**

Co-authored with Assistant Professor Yuko Onozaka and Professor Håvard Hansen, Stavanger Business School, University of Stavanger

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First author: Professor Yuko Onozaka

## **Paper 1: Salmon Aquaculture: Larger Companies and Increased Production**

### **Abstract**

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 paper 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 tonnes in 1980 to 1130 tonnes 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.

### **1.1. Introduction**

Aquaculture has been the world's fastest growing food producing industry during recent decades (FAO, 2010). Production has increased more than 20 fold from 1970 to 2010, from 2.6 million tonnes to 60.4 million tonnes. 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 tonnes in 1980 to over 2.4 million tonnes 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.<sup>7</sup> 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

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<sup>7</sup> 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 and Bjørndal, 2011).

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<sup>8</sup>. On the other hand, Nutreco disinvested in salmon farming in 2006 to focus on feed production through

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<sup>8</sup> <http://hugin.info/209/R/1652625/533535.pdf> (p.26)

their subsidiary Skretting by selling Marine Harvest to PanFish.<sup>9</sup>

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

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<sup>9</sup> PanFish continued by taking the name Marine Harvest for the merged company (Asche and Bjørndal, 2011).

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 paper is organized as follows. In the next section a brief overview of farmed salmon production is provided, before the literature on productivity growth is reviewed in section 3. In section 4 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 in section 5, and concluding remarks are offered in section 6.

## **1.2. Salmon production**

Global farmed salmon production has increased from 12,000 tonnes in 1980 to over 2.4 million tonnes 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.<sup>10</sup>

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%.<sup>11</sup> This is largely due to better growth performance,

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<sup>10</sup> Salmon trout (*Onchorynchus mykiss*) is large rainbow trout and are also known as steelhead.

<sup>11</sup> The markets for the different salmon species are well integrated (Asche and Guttormsen, 2001; Asche et al, 2005), in contrast to what is the relationship with other species (Asche, Gordon and Hannesson, 2002, Nielsen, Smit and 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

and also that it is easier to have Atlantic salmon available for the market at all times of the year (Asche and 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 the figure one can also

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that there does not appear to be a central market, a feature that can be observed for many agricultural commodities (Asche, Gjøølberg and Guttormsen, 2012).

clearly see the effect of the disease problems caused by the ISA in Chile, which reduced production of Atlantic salmon from almost 400 thousand tonnes in 2006 to 130 thousand tonnes in 2010 (Asche et al, 2009; Hansen and 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 and 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.

### **1.3. 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.<sup>12</sup> 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.<sup>13</sup> Salvanes (1993), Bjørndal and Salvanes (1995), Asche and Tveteras (1999), Tveteras (1999; 2000), Guttormsen (2002), Andersen, Roll and Tveterås (2008),

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<sup>12</sup> See Nielsen (2012) for an interesting discussion of the effects of regulations on emissions in Danish trout aquaculture.

<sup>13</sup> 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,

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) discuss 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 and Guttormsen (2006ab). 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 and Tveteras, 2013) are largely overcome by improved input mixes using new ingredients (Tacon and Metian, 2008;

Tveteras and Tveteras, 2010; Torrissen et al, 2011). Also downstream innovations like improved logistics and transportation systems are important (Asche, Roll and Tveteras, 2007), as well as more sophisticated customer relationships (Kvaløy, 2006; Kvaløy and Tveteras, 2008; Olson and Criddle, 2008; Larsen and Asche, 2011).<sup>14</sup>

Several of these innovations, for instance contract sales, are possible only because the companies have become larger (Kvaløy and Tveteras, 2008). Improved logistics have also helped fuel product development and demand growth (Asche et al, 2011) and marketing (Kinnucan and Myrland, 2002; 2005; 2007). It is also of interest to note that wild salmon producers have been able to segment wild from farmed salmon

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<sup>14</sup> 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 and Tveteras, 2009; Torrissen et al, 2013).

(Davidson et al, 2012; Fernandez-Polanco and Luna, 2012; Roheim, Sudhakaran and Durham 2012), even though the price determination process is common (Asche et al, 2005; Tveteras and Asche, 2008).

#### **1.4. Scale in Norway**

As one can see from figure 1.1, there has been a tremendous increase in salmon production in Norway. The production in 1980 was 7,800 tonnes, while it is expected to be at 1.2 million tonnes in 2012. This has been possible primarily due to increased intensification as production per license has increased, although new licenses have also been awarded.

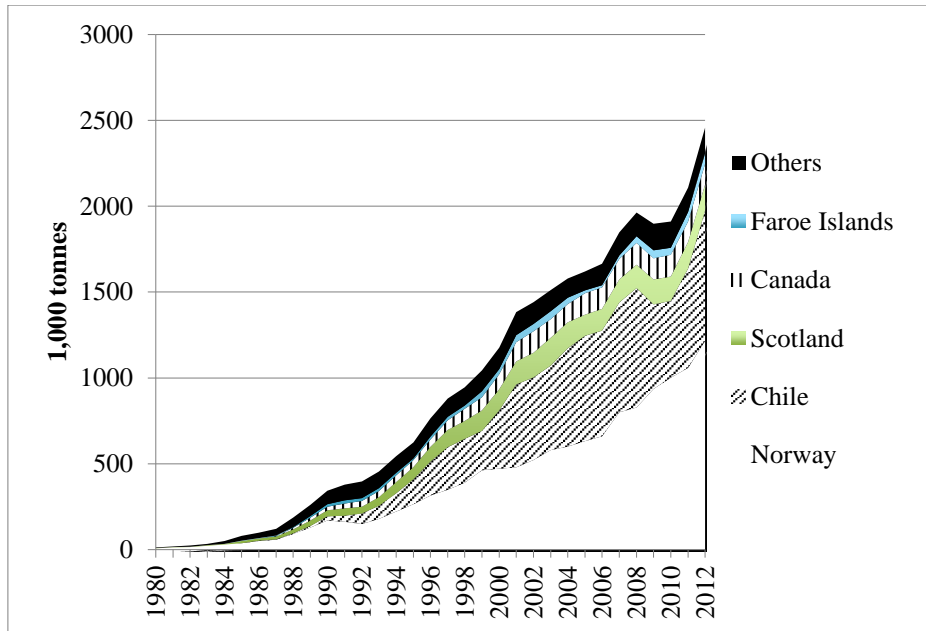


Figure 1.1. Global salmon production by country (Sources: FAO, Kontali Analyse)

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.<sup>15</sup> 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 and 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

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<sup>15</sup> There were a few exceptions as some companies operated more than one farm when the first set of regulations was implemented in 1973.

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 1.2, we show a schematic intersection for typical pen



sold in Norway in 1980 and 2010.<sup>16</sup> The pen from 1980 has a diameter of 5 meters 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 and 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.

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<sup>16</sup> This information is provided by Knut Molaug, who was CEO of a leading equipment supplier (AKVA) until 2011.

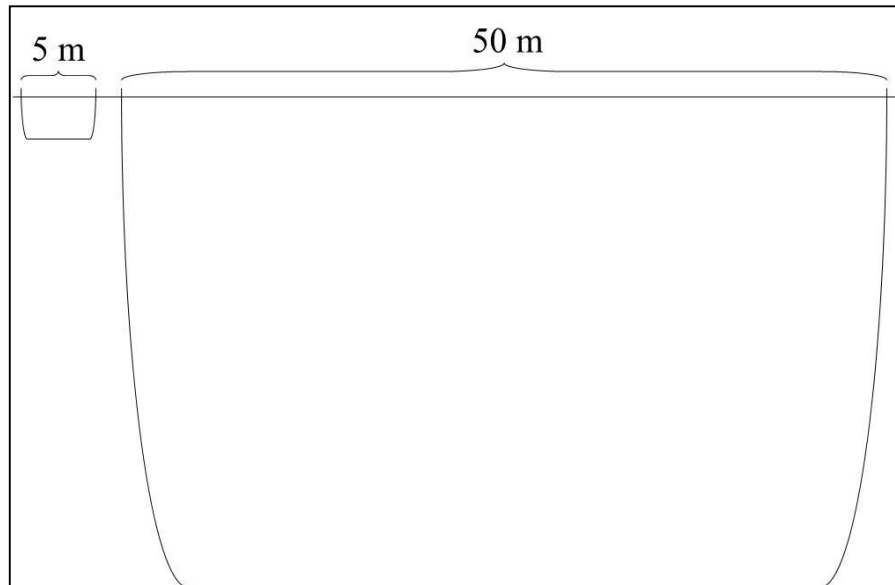


Figure 1.2. Intersection of pen from 1980 and 2010

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 1.3, the average production per license in Norway is shown. As one can see, this has increased dramatically from 26 tonnes in 1980 to 1130 tonnes in 2010. This is more than a 43-fold increase. Hence, the production has intensified dramatically over the last 30 years. While 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 and Bjørndal, 2011).

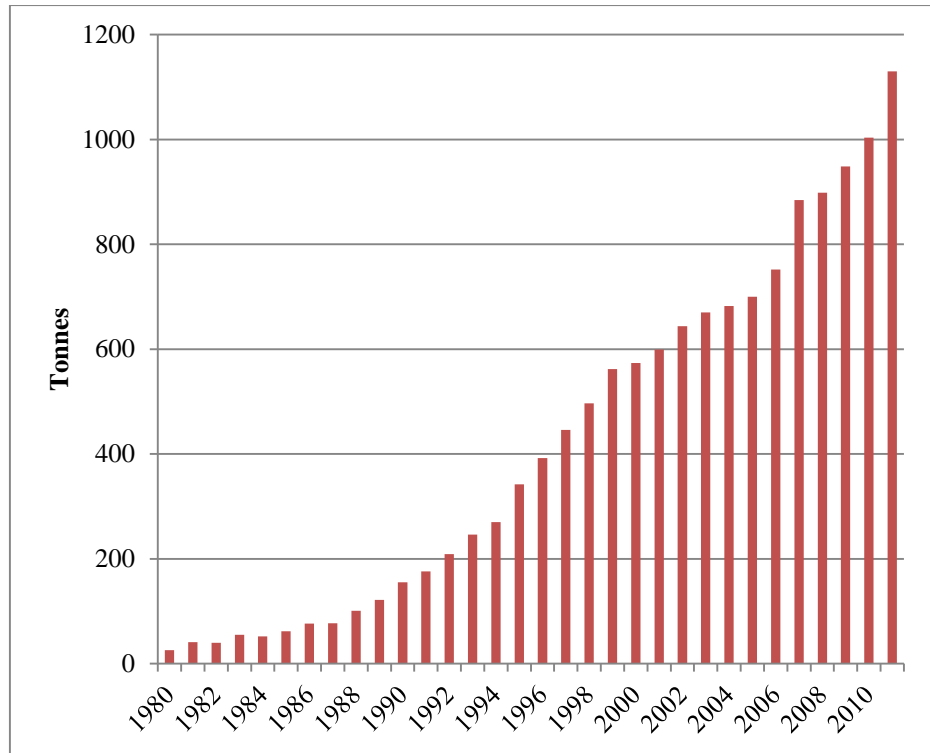


Figure 1.3. Average production per license in Norway (Sources: Norwegian Directorate of Fisheries and Statistics Norway)

Similar data is not available for other salmon producing countries.<sup>17</sup> Early on there is no doubt that the largest Scottish

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<sup>17</sup> Olson and Criddle (2009) provide an indication of firm size in Chile using export data by company.

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.

### **1.5. 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 and Tveteras, 2008; Olson and Criddle,

2008; Larsen and Asche, 2011). Still, these advantages that often occur downstream do not necessitate big production companies. For instance, while pork production in the US 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 and 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 3<sup>rd</sup> 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 will present the data by country.

### **Norway**

As noted above, 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.<sup>18</sup>

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<sup>18</sup> 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).

In figure 1.4, the number of companies making up 80% of the salmon production in Norway is shown together with total production. For 2012, 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.



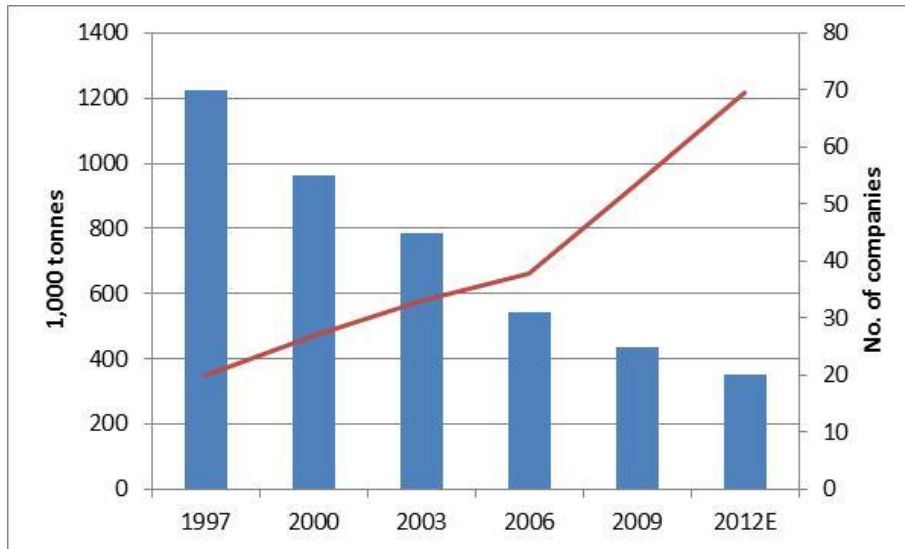


Figure 1.4. Norwegian salmon production and no. of companies making up 80% of production. No. of companies are measured by the vertical bars (Sources: Kontali Analyse and Nordea Bank)

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.

## Chile

Since the mid 1990s, Chile has been the second largest salmon producing country, although the disease crises 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 crises 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 possibly that they were harder hit by the disease crises.<sup>19</sup> 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.

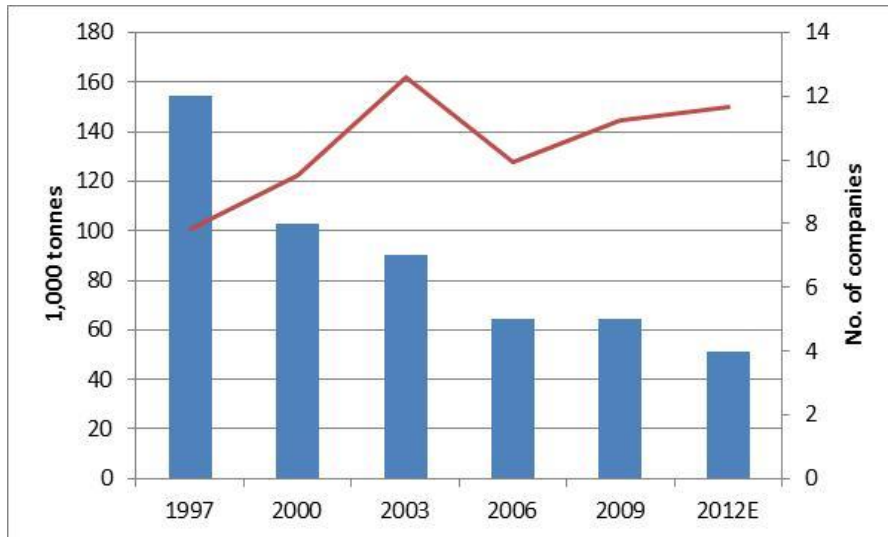
### **Scotland**

In figure 1.6, 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, and declined steadily to 5 in 2009 and is expected to be 4 in 2012. This process has occurred despite the fact that Scottish salmon

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<sup>19</sup> Note that if Asche et al (2009) is correct in assessing that the disease crises really started in 2005, the crises 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 and Criddle, 2009; Valderrama and Anderson, 2010).

production peaked in 2003. Hence, there are apparently factors beyond increased production that are driving consolidation in the industry. The 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.



**Figure 1.6. Scottish salmon production and no. of companies making up 80% of production** (Sources: Kontali Analyse and Nordea Bank)

### 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.

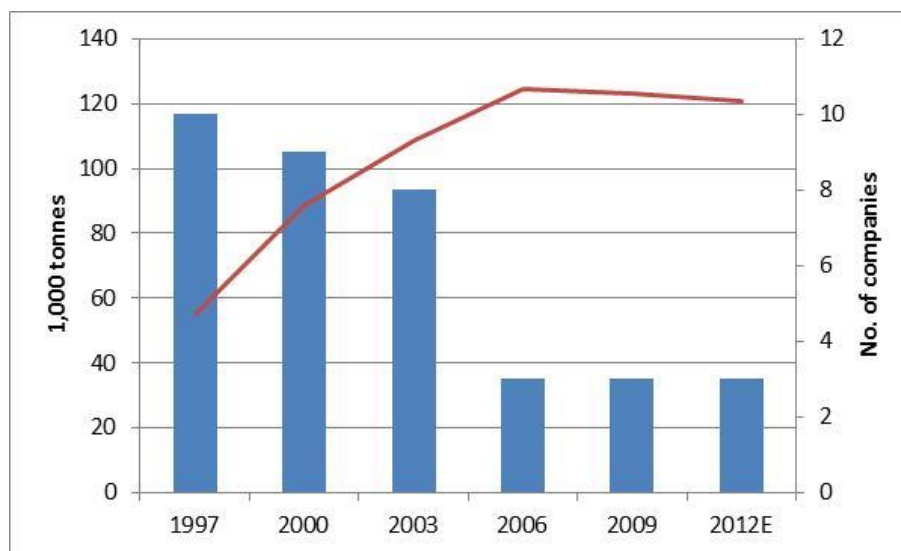


Figure 1.7. Canadian salmon production and no. of companies making up 80% of production (Sources: Kontali Analyse and Nordea Bank)

### Faroe Islands

In figure 1.8, Faroese production is shown together with the number of companies that make up 80% of total production.

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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 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 disproportionately hit by the disease problems.

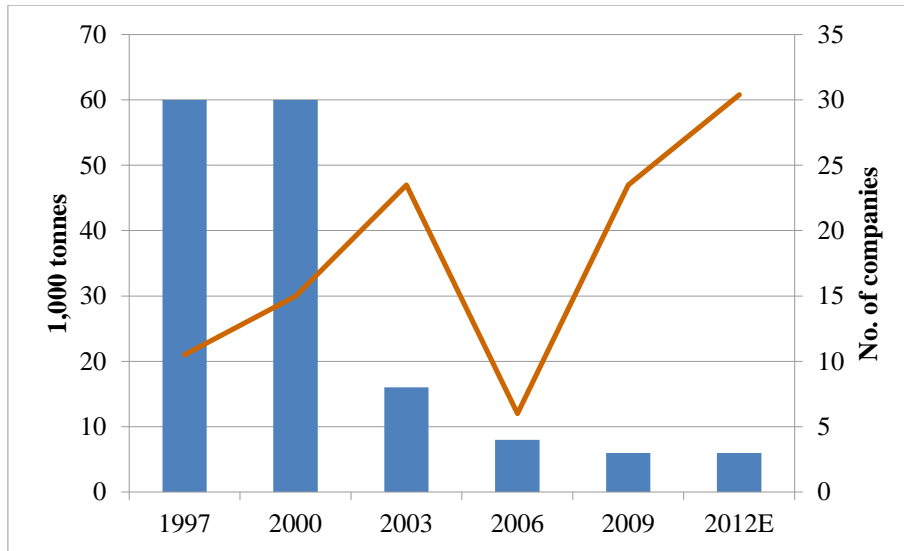


Figure 1.8. Faroe Island salmon production and no. of companies making up 80% of production (Sources: Kontali Analyse and Nordea Bank)

### 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 and 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.<sup>20</sup>

On the top ten 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 final two among the top six (Lerøy and 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

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<sup>20</sup> Lerøy and Salmar jointly own the Scottish firm Norskott, but this operation is treated as a separate firm in the data.

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 ten 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 US 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 then given as  $HHI = \sum S_i^2$  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, and 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.<sup>21</sup>

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

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<sup>21</sup> 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.

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.

### **1.6. 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 known 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 paper 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 crises; 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 do 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.

While 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-Hirschman 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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## **Paper 2: In it for the long run: Supplier-buyer relationship duration in fresh farmed salmon supply chains**

***ABSTRACT:** This paper studies salmon supply chains in a business-to-business perspective in an attempt to understand the reasons why supplier-buyer ties seem to be firm and long lasting. A general impression that farmed salmon is a highly commoditized product is scrutinized. Indicative empirical findings suggest that a claim that salmon is highly commoditized is not correct. Farmed salmon is commoditized on industrial level but not highly so, findings indicate relationship stability and underlying trading structures that depart from pure open markets in which commodity products would be traded. Findings in this paper suggest that relatively stable supplier-buyers relationships seem to be the norm. This paper study relationship duration as a proxy of the type of market fresh farmed salmon is traded in, and provide new insights into trading relationships in the supply chain.*

### **2.1. Introduction**

In less than fifty years the global salmon production has evolved into a multi-billion dollar global food production

system. Initially salmon exporters adopted the supply chains of traditional fresh fish trade, the wet-fish markets and its distribution actors, and farmed salmon was sold as any other fish commodity competing primarily on price and other basic quality parameters such as size and perceived freshness.<sup>22</sup> A spot market with pure commodity products is primarily governed by price, signaled by information about supply and demand. It is associated with discrete transactions with little relational commitment in supplier-buyer relationships between transactions because there are few differentiating factors between the products, thus eliminating information exchange beyond a standardized set of parameters (i.e. petroleum, sugar). Based on the image the salmon industry portrays of itself as a highly commoditized spot price driven

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<sup>22</sup> Hedonic prices studies show how different attributes influence price (Carroll et al, 2000; Lee, 2014; Asche; Chen and Smith, 2015). Asche and Guttormsen (2002) show that salmon prices are size dependent.

industry (Asche and Bjørndal, 2011), one would expect to find relatively uncommitted customer relationships in the industry's market channels. Commodities, in its purest forms, do not require personal relationships. They trade in open markets and offer little opportunity to increase rent through non-price related attributes and behaviors. This paper is about the degree of commoditization and industrial supplier-buyer relationships, and lends its key theoretical concepts from transaction costs economics theory (TCE) to explain observed forms of vertical coordination modes and governance forms in the salmon supply chain. The discussed transaction characteristics are biological, physical and organizational areas that through TCE-lenses may constitute barriers against a high level of commoditization of farmed salmon. The specific characteristics are perishability, biological variation and planning risks; downstream productivity race;

transformation from thick to thin markets in both retail customer relationships and salmon farming production; and consumer advocacy and information requirements. This article discusses the above-mentioned transaction characteristics in relation to open market versus contractual relationships modes of coordination. This is relevant to understand pricing mechanisms between farmer/exporters and manufacturer/retailer, and to analyze if there is a place for commitments, loyalty and differential rent between competitors and the strategy choices they make.

The shift in sales in mature markets away from traditional wet counters as 'a fish', into sales as industrially packed centerplate skin and boneless protein accentuates the barriers against commoditization of salmon products in the industrial relationships. This shift affects the supply chains and changes the ways farmed salmon is traded in industrial relations, from



basic bulk trade to a more specific and technical form of procurement. This observed change in products and procurement in salmon supply chains is similar for some other large groups of seafoods (other industrially farmed fish species, shrimps, selected wild fish species). The variety in end-consumer products formats and the variety of species has created a new sector of actors (referred to as *fish-packers* in this article) that combines this complex variation into daily offers of large series of end-consumer products sold in the self service areas within the large retailer chains' outlets. This change significantly downplay the role and importance of traditional wet market channels as intermediate channels.

This paper is organized as follows: First, consumer products, industrial supply chains and theoretical concepts are introduced. Then we discuss the theoretical concepts in relation to the above-mentioned characteristics, and finally we

analyze and discuss empirical data from customer relationship durations from three salmon producer companies.

## **2.2. Farmed salmon products, supply chains and sales**

### **2.2.1. The main industrially processed consumer market products**

A few studies have investigated aspects related to the commoditization of *smoked* salmon at consumer level in order to understand if and how salmon products can be differentiated in a commercially viable and meaningful way at consumer level (i.e. provide additional rent to the supply chain actors). Sogn-Grundvag and Young (2013) finds that although innovation develops the size of the category and consumption, a continuous addition of similar products (copycats) lead to homogeneous offers of products with few truly unique and inimitable attributes, hence they become commoditized

consumer products. This commoditization seems to be reflected by the evolution of the industrial structure of European smoked salmon production, which is increasingly concentrated. Currently the ten largest processor-firms produce 60% of the total 160 000 tons smoke and marinated salmon product weight market (Marine Harvest, 2013). Each processor can supply multiple retail competitors with similar products under different private labels, while the private label owner can choose among a range of standardized products and sizes to be sold under its labels. The products are similar to those of the competitors, and are typically generic first price-commodity products produced in large scale, semi-automated facilities. Smoked salmon products are less perishable than fresh, and allow for higher level of standardization, storage and planning than fresh formats. Returns to scale define the

productivity and price competitiveness, creating a race towards becoming the lowest cost producer.

Fresh salmon products at the consumer level have, contrary to smoked salmon products always been regarded and offered as commodities. However, there are some exemptions: tying country of origin attributes to salmon products through generic marketing (e.g. Norwegian Seafood Council, Scottish Salmon Board); initiatives tying individual retailers own quality specifications to products (e.g. Carrefour's "Engagement Qualité" and Eroski's Nature); and initiatives tying third party certifications to products (e.g. Label Rouge, Naturland, ASC). These initiatives relate to indirect attributes of salmon products and have increased product knowledge, developed preferences and affected salmon purchase behavior among European consumers (Asche and Bjørndal, 2011; Kinnucan and Myrland, 2007). In traditional bulk channels "*a fish is a*

*fish*” within the quality grades the sellers and buyers define (e.g. size, form; like head-on-gutted etc). At the moment of sales at consumer level few direct product attributes can be perceived by the consumer. They have had to rely on their own and others expert evaluation (e.g. fishmonger, retailer) to assure freshness and quality of the products. The importance of freshness and quality appearance turns well-functioning, efficient supply chains that prolong shelf life into key vehicles for higher value creation, and was from early on a priority for the industry (Asche, 2008).

With the evolution of, and currently rapidly increasing range of fresh salmon products packed in modified atmosphere (MAP) a new era of sales and marketing of fresh salmon consumer products has started (Ortega-Rivas, 2009). By establishing supply chains with unbroken, low temperatures from farm to the supermarket’s chilled counter, improving

hygiene practices in processing plants and applying MAP technologies, fresh salmon products shelf-life can be increased significantly (Ortega-Rivas, 2009; Sivertsvik et al., 2002). Fresh salmon, both as industrial raw materials and end-consumer product, has in many markets stepped up from the traditional wet bulk market channels, and transformed into high level, technical industrial products and at the consumer end, into convenient chilled marine protein. Chilled fresh products do to a larger degree fit into and compete in the same consumer space as chicken and other fresh-packed center plate proteins. Whether or not MAP-salmon processors (from here-on denominated *fish-packers*) and retailers will be able or motivated to differentiate specific salmon products from other salmon products through unique and meaningful value propositions towards consumer remains to be seen. It may be more likely to see salmon products differentiated as a product

category vs. other center plate proteins (including other seafood items). A consumers choice may more often be between protein types (i.e “for todays dinner; chicken, beef, pork, seafood or .. salmon?”) than between highly differentiated individual salmon products. In most modern European markets where chilled MAP seafood is growing, fresh salmon is the most sold seafood species (category captain) in terms of both turn-over volume and product innovation (Dekeyzer, 2010). Fresh salmon is firmly positioned within major consumer trends in relation to health, convenience and modern lifestyles. With an evolution towards large-scale MAP fish-packers it is reasonable to expect a race for innovation and range on one side, and productivity and cost-leadership on the other, where products are transformed to relatively similar products at the consumer level (an evolution similar to that of the smoked salmon sector). If so,

then differentiation would stem from indirect, yet communicable product attributes like country of origin, third party certifications and retailers private labels. Packaging, in contrary to over-the-counter bulk products, do enable a structured communication about product features. Previously that was the domain of the fish-monger. Now it can be achieved on the pack.

### **2.3. The salmon farming industry, downstream supply chains and technical sales**

The product and market development described above follows from a higher degree of production control in salmon farming [biological and technical] compared to wild fisheries. The successful growth of Atlantic salmon aquaculture enabled new standards of planning, coordination and even creation of new seafood market channels (Anderson, 2002; Asche, 2008; Smith et al., 2010a). Through productivity gains the



Norwegian salmon industry has reduced production costs to less than 33% of the cost level in the 1980s (Asche et al. 2013; Asche 1997, 2008; Tveteras 1999, 2002; Guttormsen 2002; Nilsen 2010; Roll 2013). During the same time period systematic promotion, product development and improved logistics have increased demand (Bjørndal and Salvanes, 1995; Kinnucan *et al.* 2003; Kinnucan and Myrland 2002, 2005, 2007; Asche 1996; Xie *et al.* 2009; Asche and Bjørndal 2011). In 2013 Norway's total production of Atlantic salmon reached 1.18 million tons, up from 12 thousand tons in 1980 (NSEC, 2014; Asche et al. 2013).

Supply stability have enabled establishment of direct supply chains to manufacturing and retail customers. Product availability and distribution efficiency has allowed industrial customers and retailers to grow their businesses on the basis of salmon as raw material (e.g. smoking, in-store fresh fish

category development). Salmon trading has evolved into large account technical sales of biological products. However, despite the relatively higher level of production control, salmon farming is still susceptible to a degree of random variation. Bio-physical variations and even shocks occur, and are key sources of supply and price risk and uncertainty not only in farming but along the entire salmon supply chain (Sørvig and Tveteras, 2013; Asche et al. 2009; Tveteras, 1999).

The industrial development described above has also lead to larger transactions. Annual inter-firm transaction volumes of 5 to 10 thousand tons are common in todays' industry. Thus, annual contract transactions may exceed US\$50-60mill in economic farm gate value. Envisioning that such a significant flow of goods is traded through small individual and discrete spot market deals where the second transaction is independent

of the first is difficult, even unrealistic. Therefore it is expected, particularly in larger transactions, that an open spot market is replaced by another form of coordination authority beyond price alone (i.e. contract, trust and norms, bureaucracy).

If we follow the argument that farmed salmon business is highly commoditized, the form of vertical coordination most associated with commodities is the open market mode. But, what is a commoditized product? A commodity is a product or service of uniform quality produced in large quantities that is interchangeable with another same type product from another producer. Price is subject to supply and demand, and in particular for soft commodities (perishables) futures markets is relevant to reduce risk from future selling price. Commodities trade on commodity exchange markets, and typical food commodities are grains, soybeans, and fishmeal.

If farmed salmon is highly commoditized, then its products should not differ significantly from other traded food commodities. Hence; in markets with a high degree of discrete, unrelated transactions and absence of long-term inter-personal commitments. Price would be the principal decisive authority, the final objective criteria for decision-makers.

#### **2.4. Theoretical framework: Transaction Cost Economics**

Adaptation to change is a central problem in economic organization (Hayek, 1945; Barnard, 1938). Dependent on ones definition of a firm, adaptation may be regarded either as a firms' *autonomous* adaptations to market shifts signaled by changes in relative prices. Or, they may be regarded as *cooperative* adaptations accomplished through the administration and coordination of the firm. The first

perspective on adaptation builds on a view of the firm as a production function (neo-classical), which is a technological construction. The latter regard a firm as a governance structure, which is an organizational construction (Williamson, 1998). Transaction cost theory describes a firm (hierarchy) as a governance structure, as a vehicle for coordinating actors and activities. Alternative vehicles to the firm (hierarchy) for coordination are open markets or contracts.

The boundaries of the firm is defined by its core technology (Reve, 1990; Thompson, 1967), say salmon farming and primary processing, and governance choices in relation to activities needed to perform its core function. In TCE this imply a set of governance decisions of whether to make-inside-firm or buy-in-markets. Governance then is the means by which *order* is accomplished in a relationship in which

potential *conflict* threaten to upset opportunities to realize *mutual* gains.

Transactions are the ultimate units of activity in economic organization (Commons, 1932), and contains the three principles of conflict, mutuality and order. Transactions occur when goods or services is transferred across a technologically separable interface (e.g. fresh filleted salmon transferred to smoking operation). Transactions can be governed in three archetypical coordination modes: Open-market, contracting (bi- or multi-lateral) or unified coordination (John and Reve, 2010). The mode often depend on the costs of each transaction: When the cost of selling or acquiring a good in the open market is higher than making it, the activity will become internalized, or governed by contracts. And vice versa; if the cost of coordinating an activity within company borders are higher than the market ["buy"] alternative, the activity will be

outsourced. These are, along with the independent variables that influence coordination mode: Asset specificity, Uncertainty and Transaction Frequency, the core tenants of transaction cost economics (Williamson, 1975, 1979, 2010; Rindfleisch and Heide, 1997; John and Reve, 2010). The relationship between transaction costs and the independent variables can be illustrated by the following case: When a transaction is highly problematic (thus costly) and the acquirer in question depends on the input-product for the efficient production of its own products (high asset specificity), then the acquirer would prefer to contract or integrate the suppliers' activity in order to reduce costs and risk. If the acquirer is less dependent on the input-product (low asset specificity) then she would resolve the transaction problem most efficiently through open market mechanisms (i.e. tenders and competition). Asset specificity takes a variety of forms, and

*“is the big locomotive to which TCE owes much of its predictive content”* (Williamson, 1998). Transaction costs are the costs associated with planning, adapting and monitoring economic activity, or “the costs of running the system” (Arrow, 1969; Williamson, 1996), and must not be confused with production costs. Transaction costs are categorized into ex-ante costs associated with searching, drafting, negotiating and safeguarding transactions, and ex-post costs associated with policing and enforcing agreements, adapting to changes and measuring out penalties. When a transaction is agreed (i.e. contract is signed) the transaction transforms from being in a thick market (many competing players) into a thin market. Thin markets amplify risks from specificity, e.g. thin market combined with high asset specificity may result in high switching costs and hold up risk, and a stronger need for ex-ante specification and safeguarding. Transaction cost



economics (TCE) is a product of New Institutional Economics and New Economics of Organization (Moe, 1984; 1990). However, it has also evolved into a dominant theory of the firm in the strategy field (Connor, 1991), and a dominating theory for explaining market channel evolution (John and Reve, 2010, Anderson and Coughlan, 2002). A central hypothesis in TCE is that open market coordination is the superior governance mode (Anderson and Coughlan, 2002). Alternative forms of vertical coordination to open markets rely on the existence of “market failure” (Milgrom and Roberts, 1992; Williamson, 1975). Under the neo-classical assumptions that (1) producers minimize costs to maximize profits, (2) consumers’ know prices and maximize their utility given outcome and that (3) prices adjust to equate supply and demand for each good, then open markets allocate resources most efficiently. In reality, however, producer firms can for

instance have concerns about their ability to sell the quantities at given prices in open markets. Buyers can thus face costs of searching for the adequate goods, and sellers can face costs of communicating about availability. Such transaction costs inhibits an efficient, unrestrained flow of products across companies' and nations' borders, thus creating market failure and demand for different degrees of safeguarding and adaptations that removes the transaction from an open market into an alternative mode of coordination.

## **2.5. Farmed salmon supply chain transaction costs, specificity and dependencies**

Based on observations of fresh salmon downstream market channels over time, five areas can be identified as being associated with significant levels of asset specificity. This paper discuss these areas in relation to coordination modes, and why they can be regarded as operational areas, or

variables, that act as barriers against commoditizing salmon trade to a level where pure open market coordination would be the default coordination mode.

**Area 1: Perishability, size variation, production cost/risk and planning needs**

After harvesting and gutting, a salmon has a shelf-life of about 14 days when temperature control and hygienic conditions in the supply chain are adequate. Each day lost to non-sale reduce the value of the raw-material. Thus, there is a strong urgency in allocating the volume, in a profitable way. This urgency can be defined as temporal asset specificity (Williamson, 1998). Risks and cost from temporal asset specificity for the salmon producer are accentuated by the high capital investment in farming over the salmon life-cycle (production costs), and by variations in size and quality that affect logistics and planning directly. Different markets and customers value different sizes and qualities differently, and the task of planners is to optimize

profitability through matching supply and demand. The capital asset specificity, exerts pressure on the salmon producer to, within a short time-frame, capitalize, capture and secure the maximum economic value of the slaughtered cohort. Random biological variation (size and quality) demands quick planning responsiveness and low-barrier access to global market channels for the fresh salmon products as it leaves the primary processing plant. These market channels, or customers, must be the right customers that value the deviating sizes highest. Deviating sizes are sizes outside the 3-5 kilo size band, which is the preferred size in mature industrial salmon markets (see Area 2). To pump deviating sizes into open wholesaler wet markets would quickly lead to sharp supply shift and general loss of value due to a high degree of price transmission between different channels (Asche et al, 2014). Therefore the salmon producer would have an interest in maintaining and

developing flexible longer term business relationships across customers, channels and continents. The main volume (size and quality) is often allocated through volume contracts that assure the salmon producer an efficient allocation. To illustrate the sources of temporal specificity pressures, annual harvested size distribution are shown in Figure 2.1.

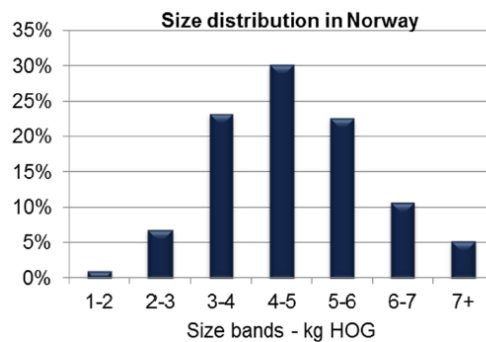


Figure 2.1: Harvest size distribution of salmon in Norway 2013 (Source: Kontali Analyse)

If fresh salmon is to be regarded as a soft commodity it would trade most efficiently through futures exchanges. The salmon

futures exchange Fishpool was established in 2006. Six years later, in 2013, only just below five percent (102ktons) of global farmed Atlantic salmon is traded in salmon futures (Fishpool, 2014). The relative low share of total traded volumes may indicate that the attributes of the products and trade are not highly commoditized. Differentiated markets for allocation of different volumes, sizes and quality, combined with temporal asset specificity, are important attributes that inhibits trade to be coordinated in an open commodity market. Hence, according to Williamsonian TCE (Williamson, 1978), these attributes create ‘market failure’.

## **Area 2: Biological variation and downstream productivity race**

In mature markets like the Western European market, the value-addition activities in the downstream supply chains are increasingly concentrated into fewer, larger secondary processing firms (primarily smokers and fish packers). The ten

largest firms now produce more than 60% of total smoked salmon in Europe. An evolution towards larger entities is seen also for *fresh* salmon modified atmosphere packaging (MAP) manufacturing. Particularly in UK an evolution towards exclusive arrangements with *fresh fishpackers* (Seachill, Seafood Co. and others) and the dominant retailer groups can be observed, but also in countries like Spain, France, Belgium and Norway the development of large scale *fish-packers* with a wider product scope than salmon is spreading (e.g. Mercadona-Caladero in Spain, Norgesgruppen-Lerøy Sjømatgruppen in Norway).

Kvaløy and Tveterås (2007) demonstrated how highly specialized large scale processing lead to sharper average cost curves, increased physical asset specificity and place new demands on vertical coordination. Old technology, typically

with a higher degree of manual labor and less scalability, have a higher average production cost while at the same time a flatter cost curve allowing for more flexibility of the volume produced (firm A, Figure 2.2).

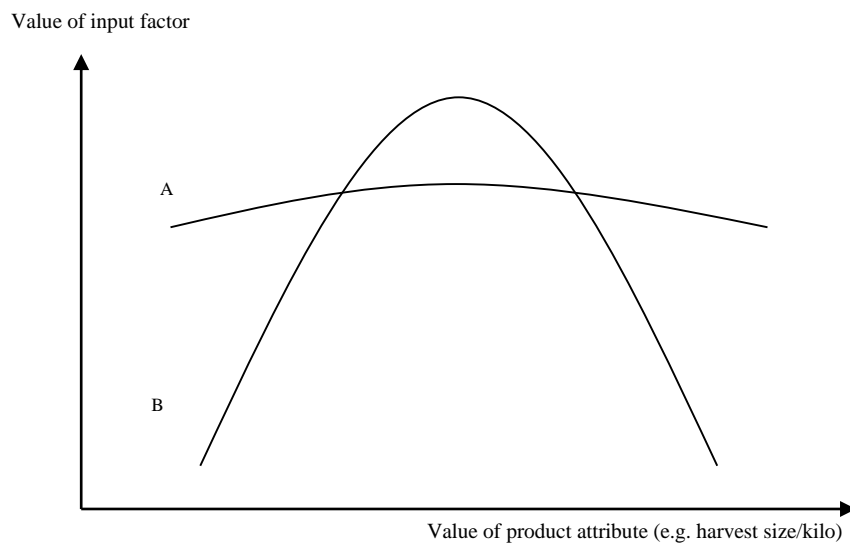


Figure 2.2. Relationships between value of input factor and specific product attribute (Source: Tveterås, 2004)

New technology, typically more capital intensive automated processing technologies, achieves lower average production



costs but often with a sharper cost curve. Hence, the flexibility of volume produced at an optimal cost level is less, while the competitiveness and profitability potential is higher (firm B).

The evolution towards large-scale, industrialized processors places new constraints on supplier-buyer relationships. Where previously a flatter average cost curve (firm A) allowed for greater variation from random biological variation (size, quality), and thus flexibility in the supply chains for both parties, new technologies require specific sizes and volumes to reach optimal average costs levels. In figure 2.3. the relationship between the value of specific sizes to old-tech and new-tech processors is illustrated (Tveterås, 2004). The old-tech processors (firm A) have a higher flexibility to process a range of raw material sizes, and can therefore to a larger extent trade in open whole-seller [wet] markets than processor B can.

To assure right volumes of right sized salmon processor B would be more inclined to write contracts than processor A, due to a significantly higher physical salmon raw material asset specificity. Hence, the processor depends on the quality of supply and suppliers to increase productivity and competitiveness.

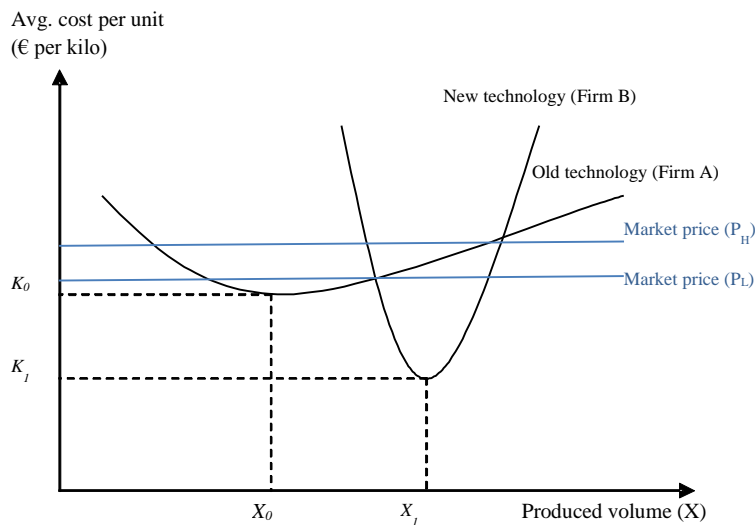


Figure 2.3. Average unit cost for «old» and «new» processing technology, and consequences of volume deviations in relation to market prices (Source: Kvaløy and Tveterås, 2007)

Let firm B be a large scale fish-packer that has a retail- or food service contract for portion packed salmon. The food service operator demands absolute uniformity for plate fill (e.g. serving tray at large scale institutional catering, for example airlines), or the retailer require fixed weight portions, i.e. invoices are based on declared and not actual weight, and should never deviate negatively for the consumer. The latter requiring the fish-packer to tightly control each portion weight to avoid economic loss. When optimal size for the fish-packer is the 3-4 kilo weight-band, then a delivered batch of 4-6 kilo weight-band imply economic losses from adapting the raw material, both in terms of product yield as well as manual labor. Deviating fish sizes also lead to a less attractive appearance of the fixed weight, e.g. 125 grams, consumer packed portion (i.e. a thin, tall slice), where the taller piece of meat even is in contact with the packaging film resulting in a

slimy impression of the final product, directly affect consumer sales and breakage. The processor, as well as the retailer thus depend on the salmon supplier for its profitability. If transactions are governed in such manner that they over time inhibit the processor from optimizing scale benefits, TCE predicts that new coordination initiatives is likely to take place. The fish-packers dependency on correct deliveries is also related to the specifications of the contracting retailer (fish-packer's customer) which adds another parameter of risk, or level of physical asset specificity and complexity to the transaction (e.g. reputational and business relationship risk, see point 3 and 4).

With growing demand for, and processing of, MAP seafood products, along with an industrial evolution towards increasing firm size and concentration in both the smoked salmon and fishpacker sectors, it is reasonable to expect

increased physical asset specificity and reduced market channel flexibility for deviating sizes. A strategy for the secondary processors would be to safeguard transactions of specific volumes through contracting. It is, however, important to note insiders' views that large scale processing does not necessarily imply low flexibility in procurement of different sizes or grades of salmon. In the smoked salmon sector, insiders report that flexibility and scale is possible to combine through developing production lines with intensive, automated and less intensive production technologies. A large product portfolio and customer base is however a condition, making channel management decisions between for instance a salmon producer and a salmon smoker an issue of market position and market power as transaction costs seem to be related to channel flexibility (market access).

### **Area 3: Transformation from thick to thin markets (retail)**

How retailers create and coordinate internal markets, and how that may influence the commoditization of fresh salmon supply, is the main topic in this chapter.

Most, if not all, retailer groups in the world safeguard their operations through defining procurement policies and detailed specifications for the thousands of product lines they have on offer. This is also the case with farmed Atlantic salmon. A retailer specifies the desired attributes of farmed salmon and farming practices, which the retailer demands documented and certified by the salmon supplier before she will be allowed to supply the retailer (become “listed” as supplier). According to industry sources the base specifications are quite similar between retailer groups, but many retailers develop extensions on top of the basic specifications to cover differentiated

private labels standards and retailers own raw material quality programs (e.g. Sainsbury's "Responsibly Sources Seafood", Carrefour's "Engagement Qualité" and Metro's "Saveurs et Sécurité"). Such extensions are competitive responses to other retailers' product offerings and communication, as well as for ethical purposes. The differentiated procurement programs and corresponding private labels (e.g. Sainsbury's "Taste the Difference"-line) are often tied up to value propositions the different retailers and brands promote to its consumers. Hence, retailers brand assets are tied to supply conditions, creating asset specificities (see Area 5 below). Table 2.1 illustrates seafood procurement requirements (points 3 to 6 are typically covered by the basic specifications that are requirements in order to become listed, while 1 and 2 are typically ongoing commercial contract negotiations related to a defined market price).

1	Price	(a) Price level, (b) linkage to market prices, (b) quantity discounts.
2	Volume and timing	(a) Total volume, (b) regularity of deliveries, (c) flexibility in deliveries, e.g. in relation to "normal" volumes and times of delivery.
3	Raw material attributes	(a) Size distribution, e.g. fillets, (b) quality attributes, e.g. colour, fat, texture, taste, (c) fresh vs frozen, (d) uniform quality, (e) shelf life.
4	Product range and differentiation	(a) Fish species, (b) Product varieties, e.g. easy-to-cook, ethnic foods, healthy foods, (c) private labels / brands, (d) consumer advertising.
5	Production process	(a) Raw materials in feed, (b) environmental effects of production, (c) animal welfare, (d) third party certification, e.g. ISO, ASC (e) traceability.
6	Transaction costs	(a) Negotiation, (b) planning, (c) control and enforcement, (d) transportation and (e) storage.

Table 2.1: Retail chains' supplier requirements, with specific references to seafood (Source: Tveterås and Kvaløy, 2006)



To what extent retailers' specifications and listing-practices in reality moves salmon-trade out of open spot [wet] markets and create new closed markets is to the knowledge of the author not studied. However, it seems that retailers' by listing a handful of suppliers mimics the supply side of commodity markets through creating multiple bilateral relationships based in detailed common specifications, creating a beneficial thin-market condition. With a few listed suppliers, product specificities are removed from the commercial negotiation about volumes, delivery scheme, price and discounts. A handful competing suppliers, a relative high transparency about expected future price (based on supply-side information), creates what is regarded a competitive price in each contract at the point of contracting.

The product and supply specification can, however, also be regarded as detailed appendices to contracts on volumes and

price. A fixed-price contract therefore in reality is far more than just a basic price contract. The empirical knowledge about salmon contracts is scarce (Vikuna and Zeng, 2010), while the use of contracts has increased substantially over the recent decades (Larsen and Asche, 2011). In TCE contracts is the governance mode in-between open spot markets and vertical integration. Contracts in the salmon industry are mainly fixed price contracts with little or no adaptation to market conditions. Some contracts, however, are price-contracts with agreed thresholds (absolute or relative measure) for adaptation when reference-price (e.g. the NOS-price) deviates from negotiated price. The usual contract time-frame is three, six, nine and 12 months. One could argue that such short contracts related to price and volume are mere extensions of spot markets. However, underlying these types of price contracts is this relative dense set of specifications that in

essence are contractual. The listing is the supplier's ticket (mechanism) to potential market access. For the retailer, listing suppliers reduce transaction costs significantly (e.g. search costs, haggling etc). At the same time, the relative high degree of asset specificity underlying the relationships also imply stronger inter-dependencies. A thin market condition thus affects both parties.

It is reasonable to expect that power in market channels become an issue in thin markets with the largest transaction. Market power seem to be, despite not being a core concept in TCE, a real issue in the salmon industries judged by recent vertical transaction events; e.g. salmon farmer Marine Harvest downstream move with the takeover of product manufacturer Morpol, and the distributor Mitsubishi upstream move with the takeover of salmon producer Cermaq.

According to salmon industry sources *“retailers may be tough on price-negotiations, but decisions are generally fair”*. The initial desire of the retailers is to reach agreements with preferred suppliers, and to assure the long-term economic sustainability of the supplier. The order of priorities are (1) competitive price, (2) right relationships (trust, proven record) and (3) contracts that removes supply uncertainties and shift focus on supply performance. *“When a price is agreed it is all about performance, and we can start working”*, (same source). The retailer’s primary concern given price-competitiveness, is the stability of the flow of products which positively affects turn-over and margins per square meter of the in-store seafood sales area. Hence, daily operations. There is a shared motivation for consistent, efficient flows between the parties. Fresh seafood is highly perishable, and provide a high level of temporal asset specificity at the supplier side.

An challenging issue with the fixed price contracts, referred by smaller industry players, is that salmon producers experience strong pressures from retailers to adapt contracts to lower prices when market price drops significantly (e.g. > 5-10%). It requires strong organization and contract enforcement efforts to protect against such opportunistic behaviors. Therefor in reality they are, according to these sources, often adjusted. In such case the contract institution in relation to price then mainly benefits the buyer (which on the other hand according to the same sources seldom accept changes when price rises). Weak price enforcement would in reality then transform fixed-price contracts into a fixed supply contracts. This particular source is from a smaller salmon supplier and signals that there seem to be real issues of market power within the supply chain that is not fully studied.

However, salmon seem to have evolved from being a fish commodity in the traditional wet and bulk market channels, into becoming an industrially manufactured technical biological product, or *a commodity at a higher level*.

If it is a commodity, however, it would imply that the retailer could relatively freely shift between its listed suppliers since their products and production methods per definition (specification) are the same. However, there seem to be specificities working against such switching behavior from the retailer, and these specificities may be tied to non-product specific characteristics, like volume availability and supply performance over time (proven record, loyalty).

#### **Area 4: Transformation from thick to thin markets (salmon production)**

Upon becoming listed the salmon producers accept a series of contingencies to products and production. In general the main

certifications applied by most producers today (e.g. Global Gap, GAA, ISO 9001, 14001, 22000) cover the areas retail-customers demand, but for different reasons retailers may demand specifications beyond basics (either own or third party certification like ASC<sup>23</sup>, freedom food [animal welfare], organic). Extensive specifications increase the retailer's physical asset specificity with the suppliers biomass under production, which are positive dependencies for the supplier. However, a negative dependency is that the salmon producer has to utilize additional resources (adding costs) to develop this continuous flow of specified products, and thus reducing trading flexibility and increasing economic dependency to the customer. With up to 30 months of adding non-reversible, extra-ordinary costs (working capital, mainly feed) increase economic risk on the salmon producers' side. The particular

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<sup>23</sup> According to the Global Salmon Initiative (GSI) the largest salmon producers have set target that ASC become a generic standard for sustainability in the global salmon industry, hence a commodity attribute for ethical reasons rather than a differential attribute for competitive reasons.

salmon cohort/biomass that now has a higher production cost per kilo than average, is valuable only in one particular (specific) relationship, and the added value/cost are lost if the differentiated salmon is not traded as agreed between the parties. The salmon supplier therefor would want to safeguard against opportunistic behaviors either through trusted long-term relationships, or some kind of long-term relational or classical contract (Haugland, 1996). Figure 2.4. illustrates the cost and risks involved for the salmon producer when supplying a certain volume of a salmon with a differentiated physical quality to a retailer. Say; the contracted volume is 1000 tons of 3-5 kilo size superior quality salmon. Let contracted volume for illustrative purposes equal 50% of a total production volume needed to fulfill the contract, due to random biological variation in size and quality. The salmon farmer must therefore farm 2000 tons to reach 1000 tons of



agreed size/quality. This number is conservative as a larger pool of farms/sites must be treated with the differentiated criteria (e.g. speciality feed) in order to be able to supply regularly throughout the year<sup>24</sup>.

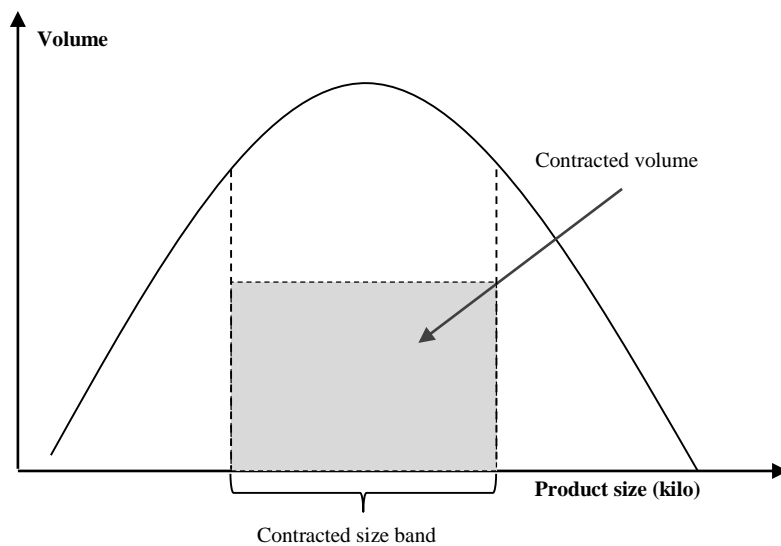


Figure 2.4: Illustration of biomass needed to deliver a highly specific contract (Illustration by author)

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<sup>24</sup> These biological and commercial dynamics are generally working against product differentiation in salmon farming, and in favor of establishing generic standards that cover the entire industry (commodity)

Hence, production costs are being added to a much larger biomass than the contracted volume, a cost and risk that must be reflected in the pricing of the volume. Deviant sizes and surplus volumes that cannot be sold in contract, must be sold in other channels as ordinary salmon or, dependent on the commercial creativity, as a value added product in a channel that can perceive and support the differentiation in question (specialty channels). Otherwise this added value/cost is lost.

Fresh farmed salmon as such a higher level technical product, or commodity, is mainly distributed to industrial and retailer segments. Salmon has in short time moved out of the traditional bulk and wet spot markets into a direct distribution channel with primarily food industry and retailers in mature markets. Fresh farmed salmon has not been strongly differentiated at the consumer level. However, as the case

above illustrate, there are some differentiation between suppliers that the final consumer may perceive through different retailers' brands or special quality programs.

Differentiation of salmon biomass under production builds physical asset specificity and creates interdependencies.

However, for the non-differentiated, generic salmon the main dependency from the salmon producers' side is to maintain low barrier access to the large consumer markets each customer represent, hence securing and maintaining a reliable set of supply chains.

## **Area 5: Consumer advocacy, regulations and information requirements**

Bio-physical variations and even shocks occur, and are key sources of supply and price risk and uncertainty not only in farming but along the entire salmon supply chain (Sørvig and Tveteras, 2013; Asche et al. 2009; Tveteras, 1999). The demand side also represent a source of uncertainty affecting salmon prices. These sources can be regional and national market access (i.e. demand for minimum prices from EU, sanctions from Russia or China), issues of market information affecting sales (i.e. deserved or undeserved negative press at consumer level), or real issues related to food safety (e.g. listeria in smoked salmon) or other attributes of the consumers concern (e.g. animal welfare, sustainability) which also tend to spread fast through mass media, consumer social media and stakeholder networks.

Real, perceived and constructed issues related to food safety and ethics receives high stakeholder attention and represent threats to the integrity of raw materials, processors, consumer products and retail banners carrying the particular products in question. Consumer advocates and other stakeholders demand transparency and accountability from retailers and food producers about food safety and ethical issues. This demand for information is often advocated through mass media and consumer activist organizations (NGO's), exerting strong pressures on the involved firms, particularly those closest to the consumer.

This is not always a single product issue. They are normally broader issues particularly retailers' face regarding their procurement policies in the field of food safety, environmental sustainability, animal welfare, quality etc. Some retailers go far in their value propositions and promises to the customers

(e.g. Sainsburys<sup>25</sup> “Responsibly Sourced Seafood” and Carrefour<sup>26</sup> France’s “Engagement Qualité”), increasing the potential damage to the integrity and image of the retailer in the consumer markets if delivery fails and promises are broken. Such business practices (i.e. branding) increases dependency on own procurement policies and suppliers, and thus increase the physical asset specificity to the products supplied. For example, if you guarantee “animal welfare” in procurement-policies, and the third-party certification Freedom Food is the chosen vehicle to safeguard this, then the retailer must be assured that both Freedom Food and the salmon supplier act with integrity. Hence, dependencies backward in the supply chain are created from the relationship between a retailers, its consumers and stakeholders in the

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<sup>25</sup> <http://www.sainsburys-live-well-for-less.co.uk/products-values/responsible-sourcing/sustainable-fish/>

<sup>26</sup> <http://rapport-interactif.carrefour.net/static/cdc/rapport-interactif-2012-EN//Offre.html>

consumer market. Specificity is expected to increase as the perceived risks of error combined with uncertainties pose a threat to the reputation of the involved retailer (see figure 2.5.).

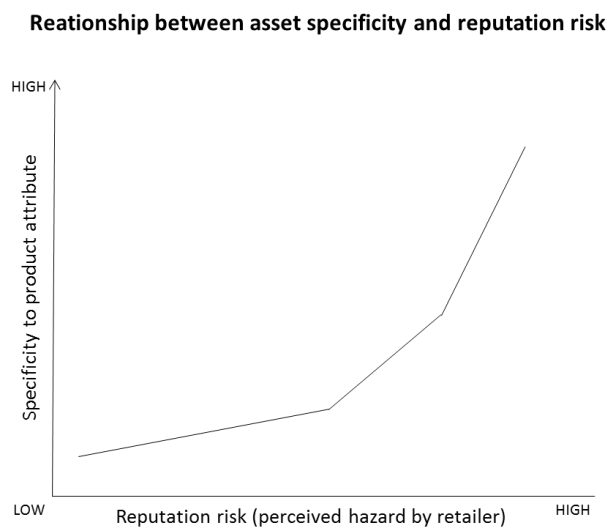


Figure 2.5: Hypothesized relationship between asset specificity and reputation risk (illustration by author)

Below are some examples that either have led to increased vertical coordination, or imply high reputational and product asset specificities in retailer-supplier relationship:

*Retailers in UK (Tesco, Sainsbury, Morrison), Spain (Mercadona), France (Intermarché) and Norway (Norgesgruppen) have tight vertical relationships with their fish packers, either through ownership or exclusive contracts. Hence, trade is happening in integrated relationships, implying that open markets are not efficient.*

*ASC-certification is relatively new, but an increasing number of species and farm-sites are being included in the scheme. Some retailers have made and communicated decisions to offer only MSC-certified<sup>27</sup> products within a defined year (e.g. Whole Food UK, IKEA in Asia, Rewe, Walmart).*

*Rewe Group promote the organic Naturland brand intensively, and retailers like Whole Foods both in the UK and in US have clear positions on organic products. French fast food chain BOCO is an example from food service with similar clear positions.*

Olson and Criddle (2008) observed that increasing demand for documentation represents a new competitive pressure in

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<sup>27</sup> Marine Stewardship Council (MSC) is the sister-system of ASC in fisheries (like FSC is in the timber industries).



Chilean salmon industry, and that certification requirements are motives for vertical and horizontal integration. It is clear from practice that documentation and subsequent flow of information require increased coordination in the supplier-buyer relationships. When risk events occur, like a real food safety issue (e.g. listeria contamination) or an unfounded, yet highly distributed negative documentary is aired on TV, the flow of information between the parties can become substantial. Especially when mass media is involved, time pressure is high and there is a higher risk for reputational damage. Efficient and effective exchange of specific high integrity information can rescue difficult situations. In the case of for instance listeria, information is not sufficient, but product traceability and control becomes crucial. This requires very specific capabilities within the supplier.

Information and certification is not a physical product issue, but a product of intangible assets related to a suppliers capability to maintain, gather and share relevant information<sup>28</sup>. Non-physical attributes of salmon trade is therefore expected to be a source to specificity that promote customized coordination efforts as well as longevity in business relationships. Hence; a capable supplier reduces a buyers risk of reputational damage when an event gets real serious.

## **2.6. Stability in supplier-buyer relationships**

In a pure commodity market, one expect relatively high indifference about who trades with who as long as the products are standardized/commoditized. Observed long lasting relationships would imply that buyers and sellers are not indifferent, and that the product is not a commodity in the purest sense. The author has been given access to data on

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<sup>28</sup> The annual reports of large producers like Cermaq, Lerøy, Salmar and Marine Harvest all agree about the strategic importance of quality control, assurance and documentation.

customer relationship duration in three distinct salmon producer companies operating in different countries and predominantly trading salmon in their regional home markets. The data set includes information about volumes sold per customer and channel in relation to total sales over a time period of five years. In table 2.2. the duration is described, and further an econometric analysis on the data-set is performed.

The information in table 2.2. clearly show that three producer companies exhibit longevity in relationships, although with different measures. The top 20 customer lists of producer 1 and 3 is barely changing in terms of individual customers, with 15 of the original 20 customers in Year<sup>1</sup> still on the list five years later.

<b>Table 2.2: Change in Top20 customer lists.</b>		<b>Year1</b>	<b>Year1+ 2</b>	<b>Year1+ 4</b>
<b>Producer companies</b>				
Producer -Co 1	Year1-Top20 customers included every year	20	16	15
	Year1-Top20 customers' share of Top20-volume	1,0	0,86	0,74
	Share of total production, Top20 customers	0,88	0,77	0,71
	Volume index (100= Year1 production volume)	100	118	149
Producer -Co 2	Year1-Top20 customers included every year	20	14	8
	Year1-Top20 customers' share of Top20-volume	1,0	0,87	0,83
	Share of total production, Top20 customers	0,92	0,87	0,77
	Volume index (100= Year1 production volume)	100	102	124
Producer -Co 3	Year1-Top20 customers included every year	20	18	15
	Year1-Top20 customers' share of Top20-volume	1,0	0,97	0,75
	Share of total production, Top20 customers	0,79	0,71	0,43
	Volume index (100= Year1 production volume)	100	93	115

Table 2.2: Customer relationship duration in salmon production (industry sources)

The original customers represent  $\frac{3}{4}$  of total volume of the 20 top customers five years later (Year<sup>1+4</sup>), which is a significant share of a growing business-volume (note the volume index).

Producer 3, however, integrated parts of their activities with another company between Year<sup>1+2</sup> and Year<sup>1+4</sup>, which opened new market channels and lead to changes in total proportion of sales to the original Year<sup>1</sup> customers. Nevertheless; 15 of the original top 20 remained among the top 20 Year<sup>1+4</sup> list. Producer 2 shows a different pattern, but still with a similar development as producer 1. The number of original Year<sup>1</sup> customers on the top 20 list decreases (due to mergers), but the proportion of remaining top 20 of total annual sales in Year<sup>1+4</sup> remain high. It is a high degree of similarity in sales growth in the supply chains of producer 1 and 2. Most of the customers on the Year<sup>1</sup> list had a customer history of between 5 and 10 years prior to Year<sup>1</sup>. Hence, these customer relationships are stable over time. Asche et al. (2013) found that salmon markets are not highly concentrated, thus we can theoretically downplay market power as a strong explanation for longevity

implying that longevity is an issue of choice by the relationship partners due to transaction costs (or loyalty, as the phenomenon would be explained in marketing literature).<sup>29</sup>

It was not possible to achieve comparable data from the food industry (VAP and Smoked salmon sector), but industry sources in these segments confirm a pattern of long-standing customer relationships in the salmon supply chain. Particularly manufacturing/fish packer-retailer relationships are stable, although very sensitive to price. Among intermediate firms (traders, distributors) a similar pattern of relationship duration was also reported. All industry sources concur with this surprising stability.

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<sup>29</sup> Asche et al (2011) show that market power is not being exploited for salmon in UK retail.

## **2.7. Empirical analysis of duration of customer relationships**

Different types of asset specificities and uncertainty problems seem to give rise to transaction costs and risks associated with switching supplier or buyer. These specificities are identified as possible explanation to why there are incentives to establish supplier-buyer relationships that are more durable than in typical spot markets.

In this section the dataset presented in last section is exploited to test empirically determinants of customer-relationship duration. An ordered probit model is used to estimate relationships between an ordinal dependent variable and a set of independent variables (Greene, 2012). In our case the ordinal variable is relationship duration, which takes the value 0 if the customer is present only in Year 1, value 1 if the customer is present on the top 20-list also in Year 1+2, and value 2 if the customer is present also in Year 1+4.

An underlying score is estimated as a linear function of the independent variables and a set of cutpoints. The probability of observing outcome  $i$  corresponds to the probability that the estimated linear function, plus random error, is within the range of the cutpoints estimated for the outcome:

$$\Pr(\text{outcome}_i = i) = \Pr(\kappa_{i-1} < \beta_1 x_{1i} + \beta_2 x_{2i} + \dots + \beta_k x_{ki} + u_i \leq \kappa_i)$$

$u_i$  is assumed to be normally distributed. We estimate the coefficients  $\beta_1, \beta_2, \dots, \beta_k$  together with the cutpoints  $\kappa_1, \kappa_2, \dots, \kappa_{I-1}$  where  $I$  is the number of possible outcomes.  $\kappa_0$  is taken as  $-\infty$ , and  $\kappa_I$  is taken as  $+\infty$ . All of this is a direct generalization of the ordinary two-outcome probit model.

Our explanatory variables are (1) producer dummy variables which identifies if there are producer-specific effects influencing the duration of the customer relationship, (2)



customer type dummy variables for retailer and traders, with processors as the base category, and (3) the traded volume of salmon in Year<sup>1</sup>. It is not asserted here that the explanatory variables measures directly factors related to transaction cost economics, but if there are significant differences in the structure of transaction costs across e.g. customer types, then this could be captured in the coefficients associated with the customer type dummies. Table 2.3 presents the empirical results from the estimated ordered probit model. Producer company 1 is the base company (omitted company), and sector 1 is the base sector.

Variables	Parameter Estimate
producer_co_2	-0.545 (0.610)
producer_co_3	0.723 (0.565)
sector_no_2	-0.280 (0.481)
sector_no_3	-0.205 (0.413)
lncustomer_vol_tons_Year1	0.392* (0.222)
Constant	1.557 (1.951)
Observations	58
Log likelihood	-45.42

Standard errors in parentheses  
\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 2.3: Empirical estimates of determinants of the duration of supplier-buyer relationships

According to the empirical estimates there are neither producer-specific effects, nor buyer type specific effects on the duration of buyer relationships. The only significant effect is the traded volume of salmon, which is positively associated with duration, at the 90% confidence level. The effect of a change in traded volume on the probability of the

buyer-customer relationship lasting until Year<sup>1+4</sup> (ie. outcome 2) is shown in table 2.4. All other variables are evaluated at their sample means. We see that the probability increases from 19% at the minimum traded volume, via 59% for the sample mean volume, and then to 87% for the maximum volume. In other words, the probability of buyer-customer relationship lasting during the entire sample period increases significantly as the traded volume increases.

Value of ln(volume)	Est. Prob.	St.error	t-value	p-value
Min	0.197	0.174	1.13	0.257
Mean-SD	0.389	0.127	3.05	0.002
Mean	0.586	0.071	8.30	0.000
Mean+SD	0.764	0.105	7.28	0.000
Max	0.868	0.116	7.46	0.000

Table 2.4: Probability of buyer-supplier relationship lasting until Year1+4 (outcome 2) for different trade volumes, with all other explanatory variables evaluated at sample means

These findings are not without methodological issues. The data are limited to three companies that are non-randomly

selected, and their top 20 customer lists over a five year period measured at three points. There is also an obvious relationship between duration and customer size as the top 20 is measured by volume purchased. Many of the customers that for different reasons fell out of the top 20 list are still in the more extended customer lists (confirmed ex-post).

However; although it is expected that size and duration return a strong statistical relationship the findings are supported by the descriptive tables above (table 2.3 and 2.4). For all three producers the original Year<sup>1</sup> customers present in Year<sup>1+4</sup> represents >74% of the total top 20 share. This provide to important observations:

- 1) *The supplier-buyer relationships are surprisingly stable*
- 2) *The largest customers grow their salmon business with growing supply*

Reasons for customers not to grow at the rate of the producers' production evolution can be strategic procurement (split volume among more suppliers), strategic sales (concentrate limited volumes to lesser customers) or simply stagnating salmon business with the particular customer. Despite methodological issues, the general tendency explained by this empirical data is conclusive. The salmon sold by these three companies are traded in long-lasting business relationships.

These findings falsify the null-hypothesis. It seems that salmon products and trade is not highly commoditized. This will be discussed in the next chapter.

## **2.8. Discussion and conclusions**

At the end of one of many long conversations with industry sources I asked a 'hands-on' and very experienced salmon sales top leader the following question. "It is claimed that

salmon trade is highly commoditized, do you agree to that?"

After 15 seconds his response was "I both disagree and agree".

And then he defined the trade (with retailers) to be based 75% on product commodity issues and 25% on proven relationships. "The retailers know very well the market prices, contracts are a mutual safeguarding strategy, and once a contract is signed then everything is about performance". This comment may be representative of the findings in this paper.

Long-lasting supplier-buyer relationships may be explained by specificities involved on both sides of a relationship. Temporal asset specificity would motivate salmon producers to maintain stable relationships, and both product specificity and reputation asset specificities are mechanisms that could explain the retailers and industry's motivation for relationship maintenance. We have seen from the discussion about specificities and contracting that what at the outset seem as

contractual extension of spot markets (fixed price contracts) often are based on dense, detailed specifications about products and production methods. Hence, contractual relationships based on voluntary adherence to retailers specifications in exchange for market access (listing) is common. Quarterly reporting from industry actors about contract share are related to fixed price contracts, which according to industry sources increase in volatile times. However, the trading infrastructure underlying salmon producers and their largest customers seem stable and specified, allowing involved actors to focus on improving supply chain performance in established relationships rather than switching between customers and continuously haggle over specifications and price. Higher admission to contract, given by Board of Directors of listed salmon companies, or variation in admission to contract may also indicate the degree

to which the salmon producer operates in contractual markets (retailer/industrial markets) and not in the traditional wet market channels.

From the empirical data one can also speculate whether or not both sides of relationships are strategic in that preferred supplierships or customerships are prioritized under changing supply conditions, for instance when supply is scarce a salmon supplier would prioritize allocation to its strategic customers and vice versa. Note that the timeframe included the Chilean ISA-virus crisis, which led to significant reduction in supply to the market (Asche et al. 2009), implying loyalty to strategic customers during a timeframe the supply side held the upper hand.

Although it is beyond doubt that price is the decisive authority in salmon trade, the relationships seem more concerned about the flow of products and there is a kind of eagerness to



conclude on commercial terms in order to continue the stability and cooperative adaptations of the day-to-day business. The observed pressures reported from smaller scale farmers to adapt contracted prices to changes in market conditions by the retailers and industry customers imply, however, that the commercial sides of the relationship closely monitors and controls the economic parameters of the relationships.

Some quick visits to a few of the leading salmon producers' websites reveal that they invest in maintaining relatively large sales departments, with key account management structures and responsibilities. Such structure support the findings that maintenance of customer relationships are a priority. It is not clear if it is allocation problems (temporal specificity) or segment profitability that motivates the construction of large sales organizations. However, they exist for a fact, and we find in our study that relationships in the trade have long duration.

*The main questions, however, are: Is there a positive differential return from other attributes of the trade relation beyond the market price? Is there a premium on stability? Is a kind of loyalty that provide differential positive returns present in the industry's supply chains?*

The questions have been asked often, and up to now there has been no conclusive answer to these questions. Financial EBIT/kilo comparisons between producers have not indicated a differential market premium compared to competitors. However, these measures are coarse and do not explain more refined performance measures (e.g. per segment, with or without contracts, per duration, size distribution). In the equation of a differential premium, reduced transaction costs must also be included. Long lasting and proven relationships that operate like a steady machinery underneath a price volatile ceiling will necessarily reduce transaction costs

significantly, in what would otherwise have been a highly pressured sales and planning reality where every batch of salmon was traded through discrete deals as commodities in an open market.

The above mentioned industry source indicated that “the trade (with retailers) to be based 75% on product commodity issues and 25% on proven relationships”. In a quantitative language this would imply that the preferred supplier could achieve a higher margin over competitors in that particular relationship. However, the question may not be about how much higher the price differential is. E.g. when four competitors have the same bid (+/- a small proportion) the question may not be how much higher the margin of the preferred supplier could be, but how much lower the next best alternative would have to go in order to make the customer switch. This would be decided by the market-condition *within* that very particular closed retailer-

operated, multiple bi-lateral salmon market. Only the retailer could provide answer to this question, as the retailer is the only one who knows the comparative information and the rationality underpinning the final choice. From the data however it seems that the final choice is to continue to trade with the preferred supplier as long as the price is competitive, and given the longevity through good and bad years the industry seem to have fairly well organized mechanisms to define market prices.

A practical application of this non-commodity rent-fraction in the supplier-buyer relationship would be to stipulate the downward threshold rather than the upward difference. An example from within a closed listed market could be: Let the average futures prices (market price) over the coming year be NOK36, but the industry have reasons to believe that it is too low so the agreed price between the buyer and the preferred

supplier is NOK37. If the non-commodity rent-fraction was 25% then the theoretical *switching price* for the less preferred supplier would be NOK 27.75 ( $37 \times 0.75$ ). For any contract that is a too significant gap, and thus unrealistic. But thinking along those lines: Could the value a retailer attach to a proven supplier be 3%? In that case switching price would be NOK 35.90. The competing suppliers would however have alternatives in which a NOK 37 price is achievable with other customers, and therefore a discount of NOK 1.1 from expected future price - if the hypothetical contract was a 5 kton contract - would imply that the competitor would have “pay” NOK 5.5 mill. to make the buyer switch, which would be irrational in a functional market place. We do not know the value a buyer set on a proven relationships (function, trust, available volumes, quality), but from the observed duration of relationship a fraction of non-commodity value is expected to exist. This

may be as simple as the value of saved transaction cost or a premium on all year volume availability. This information is not known.

Recommendations for future research would be to perform a full-fledged transaction cost analysis in collaboration with salmon producers, including contractual relationships. A research program related to understanding the consequences of fish-packer industry segment evolution on wild and farmed seafood would also provide useful strategic insights to producers and involved stakeholders from public and scientific communities. The relationship between generic industry agreements over standards and further commoditizing of salmon would shed light issues of strategic and operative interest. Industry-wide common, or harmonizing, standards would make local standards unnecessary and eliminate costs of controlling and policing

adherence to multiple third-party certifications with only marginal differences between them.

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### **Paper 3: Growth and Innovation in Marine Aquaculture: More Species, Slowing Growth**

#### **Abstract**

Global aquaculture in general and marine aquaculture in particular are still growing. However the growth rates during the decade 2000–2010 were lower than in the preceding decades. We find that the growth of aquaculture in different environments has been associated with the entry of new species and countries. Measured with the Herfindahl index, this growth has led to lower concentration levels in the species and country dimensions. Still, a limited number of species and countries continue to dominate marine aquaculture in terms of volume. At the individual species and country sector level, we find that many sectors have failed to grow and instead have stagnated and declined. We discuss factors that influence the growth of aquaculture sectors, such as innovation, externalities, and external returns to scale. In an econometric analysis, we fail to find strong evidence of an exogenous decline in the growth rate over time for marine sectors after we have controlled for other factors. The results suggest that the growth rates of aquaculture sectors in general and marine sectors in particular may be related to external economies of scale and learning effects.

### 3.1. Introduction

Securing enough nutritious and sustainably produced food to meet the need of the growing population is one of the greatest challenges at present time. Population growth, combined with an increasing middle class may double demand for food by 2050 (Diouf 2009). There is a need for increased animal protein production, and increased output from aquaculture is a necessary contribution to solve future food security challenges (Kutty 2010; Duarte *et al.* 2009). The health aspects of seafood diets accentuate the demand for aquatic proteins beyond the mentioned global demographic drivers, and is related to wealthier and healthier lifestyles (Anderson 2002; Asche 2008; Asche *et al.* 2009). A large and growing body of scientific research has documented the benefits of seafood in the human diet (Nesheim and Yaktine 2007; Food and Agriculture Organization/World Health Organization, 2011). Consumers will demand not only more seafood but also



increased product quality and diversity as they become wealthier (Jensen 2006).

Despite local and global constraints due to environmental challenges and competing user interests, aquaculture must provide most of the future growth in seafood production, since most of the world's fish stocks are fully exploited or over-exploited (Smith *et al.* 2010a). Furthermore, aquaculture is better positioned than fisheries to provide the product quality and diversity that future consumers will demand, because the higher degree of control of the production process facilitates innovation in production processes and products (Anderson 2002; Asche 2008; Asche, Roll, and Tveterås 2009).

The rapid innovation-driven expansion of intensive, commercial aquaculture in the decades after the Green

Revolution in the 1970s has been described as a “Blue Revolution” (Asche, 2008), and has been highlighted in influential publications such as the Economist (2003a,b). Aquaculture is expected to be a major source of protein for the growing and more affluent global population (FAO 2008, 2012). However, there are concerns about the constraints facing aquaculture, the lack of research on, and development to improve, productivity and sustainability, and the consequential effects on future growth (FAO 2008; Bostock *et al.* 2010; Gjedrem *et al.* 2012; Gjedrem 2012; Tacon *et al.* 2009; Tacon and Metian 2008; Watanabe *et al.* 2002).

Among aquatic environments, marine aquaculture has been touted as the most promising in terms of future production growth, partly due to the potential availability of vast areas (coastal oceans). Marine aquaculture represented 47% of

global aquaculture production in 2010. However, in terms of marine protein production, the fish and crustaceans sectors accounted for only 10.6% of the global production, while freshwater sectors produced 79.2% of the total quantity.

In this paper, we examine the following issues: How is global aquaculture production, and in particular production in the marine environment, developing? What are the potential determinants of growth and stagnation in aquaculture? What patterns of growth do we see at the more disaggregated level, in individual country and species sectors? Which factors statistically co-vary with growth rates in aquaculture sectors, particularly marine sectors? Finally, we provide a summary and draw implications for the future prospects for marine aquaculture.

### **3.2. Global Aquaculture Production Developments**

Global aquaculture involves numerous species and countries, with production taking place in three distinct types of aquatic environments: marine, brackish water, and freshwater. Among the 194 registered species in marine environments, the dominant species in terms of volume are seaweeds and mollusks. In brackish water environments, crustaceans (shrimp) dominate among the 147 registered species, and carp fish (cyprinids) dominate among the 257 registered species in freshwater environments (the six largest carp species represent 65% of the total freshwater volume output). The total aquaculture output in 2010 was 78.9 million tons (FAO 2013). This is 4.7 times the volume produced in 1990 and 89% more than in 2000, which illustrates the growth of aquaculture over the last few decades. Marine aquaculture represented 46.5% of the total global volume, brackish water aquaculture 6.6%, and freshwater aquaculture 46.9%.

In the following, we describe the production of cultivated fish and crustaceans in the three types of environments. We exclude seaweeds and mollusks partly because the potential for future growth through breeding seems more limited than for fish and crustaceans and partly because many of these species have low unit value.

In 2010, the global production of fish and crustaceans (FC) was 44.9 million tons, as shown in Figure 3.1, which represents 56.9% of the total aquaculture production. The share of fish and crustaceans from each environment is different from the shares of each environment of total aquaculture production, with the marine environment representing a mere 9.1% and freshwater dominating with an 80.6% share in 2010.

A source of concern for global aquaculture in general and marine aquaculture in particular is the decline in the growth rate for the 2000–2010 period compared to the previous decades, as shown in Figure 3.1. Total aquaculture has declined from a 230% increase during 1980–1990 to 100% in 2000–2010. Marine aquaculture has declined from 216% during 1980–1990 to 90% during the 2000–2010 period.

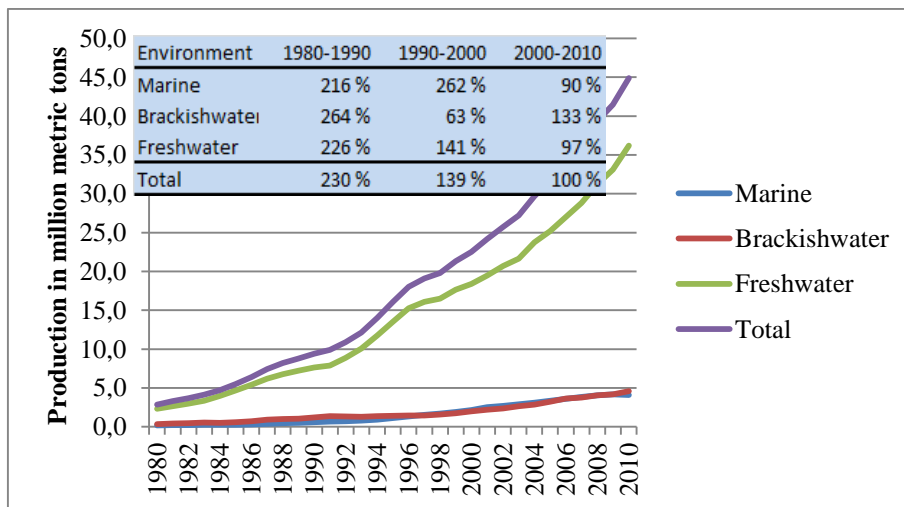


Figure 3.1. World Aquaculture Production of Fish and Crustacean by Aquatic Environment 1980–2010 (Source: FAO Fishstat)

ESSAYS IN AQUACULTURE ECONOMICS AND MARKETING

Marine and brackish water production since 1980 has represented 15–20% of the world’s FC aquaculture, as shown in Figure 3.2. The share of marine aquaculture was 9.9% in 2010, while the brackish water share was 10.3%. The marine aquaculture share of global production increased from the 1980s until the early 2000s, but has since stabilized and even declined slightly.

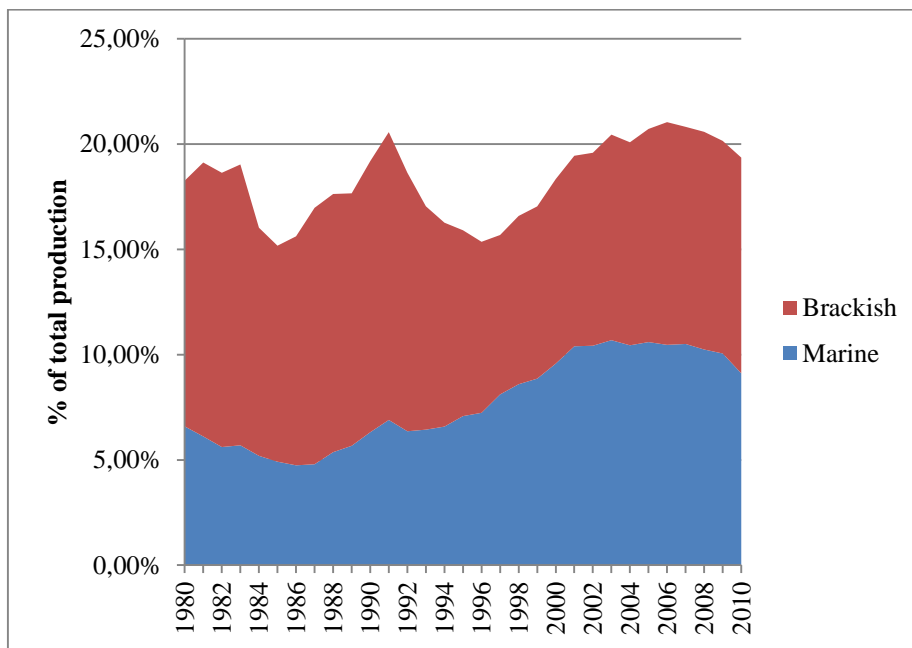


Figure 3.2. Marine and Brackish Water Sector Share of Global Production of Fish and Crustaceans, 1980–2010 (Source: FAO Fishstat)

All environments experienced year-on-year increases in the number of species involved in FC aquaculture from 1980 to 2010, as shown in Figure 3.3. FAO registered 101 species in marine environment statistics in 2010, almost four times the number registered in 1980 (27 species). A similar development is found in brackish water and freshwater. Even if more species are being produced in freshwater aquaculture, the average production volume per species is also higher since freshwater production volume is several times higher.



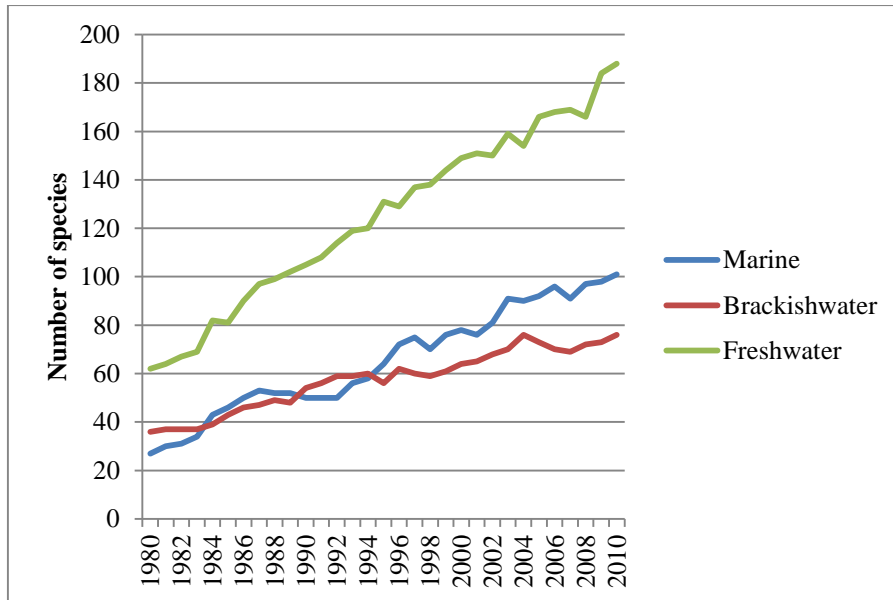


Figure 3.3. Number of Fish and Crustacean Species by Environment, 1980–2010. (Source: FAO Fishstat)

Although the number of species has increased in all environments, the lion’s share of the FC volumes are produced by the top 15 species. In 2010, the 15 largest species in marine environments produced 83.4% of the total marine volume. In brackish water, the number was similar (80.5%), and in freshwater, the percentage was 96.8%. Other species together represent less than 20% of the global FC aquaculture.

To analyze the stability in species over time, we investigate the historical share of the production volume of the largest 15 species in 2010 over the last two decades, as shown in Figure 3.4. Although the volume share of individual species has shifted within each group of species and each environment<sup>1</sup>, the analysis shows a high degree of stability of the largest species. The species that were the leading species in 1980 largely remained the leading species in 2010.

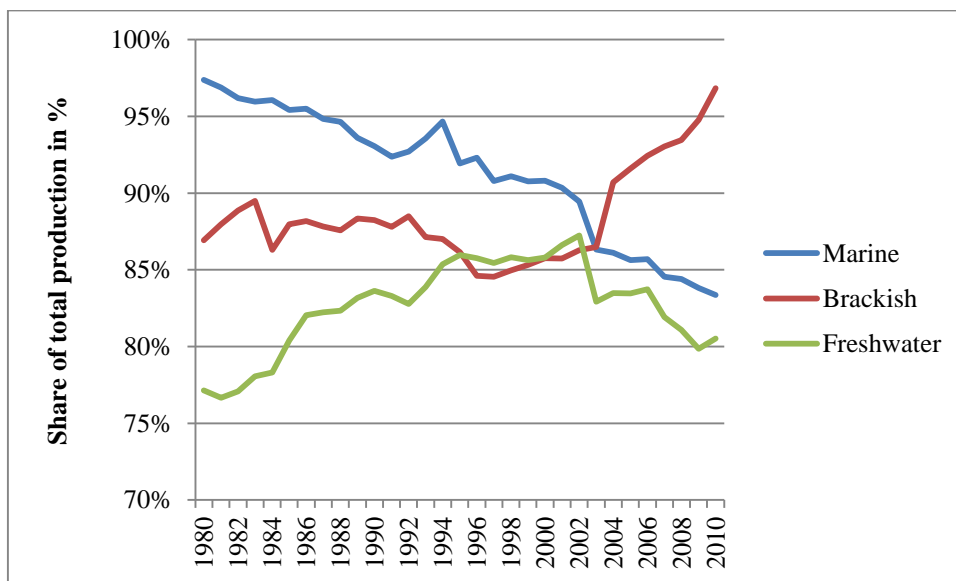


Figure 3.4. Historical Share of Total Production of the Top 15 Species in 2010. (Source: FAO Fishstat)

The concentration measure commonly used by competition authorities is the Herfindahl index (HI). The index is calculated the same as Simpson's D, which is commonly used in ecology to measure diversity. The index is the sum of the squared market shares of each unit (e.g., species, country) over all units. HI values below 0.15 indicate "low" concentration (or high diversity in ecological terms), values from 0.15 to 0.25 "moderate" concentration, and higher than 0.25 indicate "high" concentration.

The Herfindahl indices indicate that freshwater environment FC species have diversified since 1980, as shown in Figure 3.5. Marine species were moderately concentrated in 2010, after having experienced a significant decline in concentration since 1980 as new species emerged.

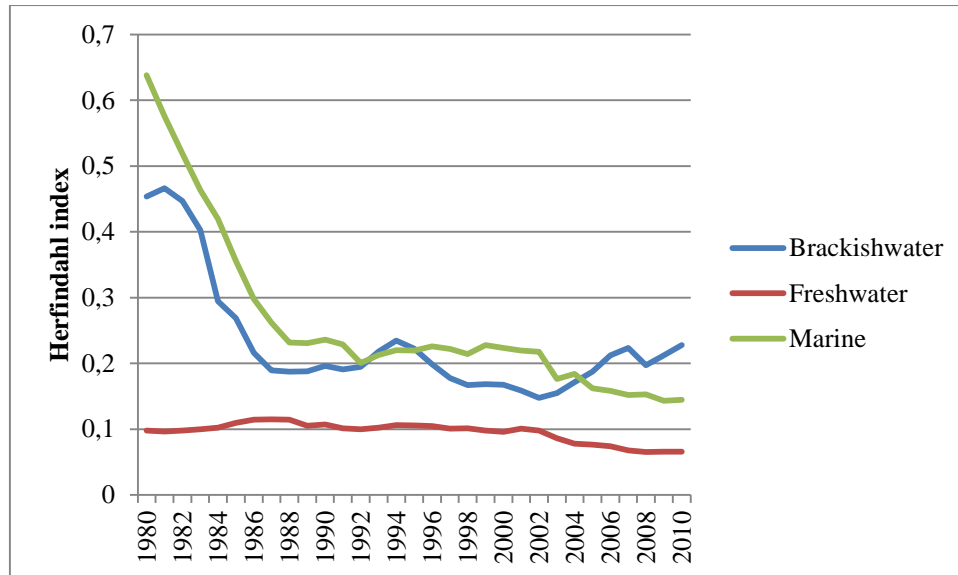


Figure 3.5. Herfindahl Index for Fish and Crustacean Species by Environment. (Source: FAO Fishstat)

The finding that FC production is moderately concentrated according to the Herfindahl index must be understood alongside the findings in Figure 3.4, that a limited number of species represents the majority of the output. However, aquaculture is still far from the situation of terrestrial meat production, where a handful of species represent most of the output.

A similar exercise with countries involved in FC aquaculture in different environments, according to Figure 3.6, shows the development toward low and moderate concentrations. Freshwater environments differ from marine and brackish water due to the dominant share of freshwater production in China. In terms of countries involved, the freshwater environment is highly concentrated. The concentration without China is also provided in Figure 3.6, and shows that without China the concentration of countries in the freshwater environment is low.

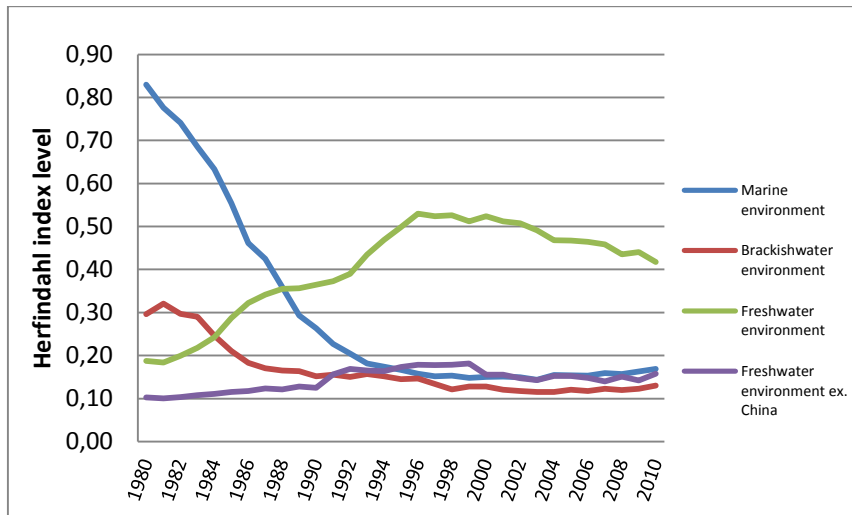


Figure 3.6. Country Concentration of Fish and Crustacean Aquaculture Production Measured with the Herfindahl Index

Similar to what we find with species, the 15 largest (and even fewer) countries represent the majority of the produced fish and crustaceans. In marine environments, the 15 largest countries represented 93.8% of the FC production in 2010; in brackish water, the share was 98.3%, and in freshwater 95.9%.

### **3.3. Potential Determinants of Aquaculture Growth**

To understand the development of aquaculture production at the aggregate global level, and the opportunities and barriers for the future, one also needs to understand the factors that can influence growth at the individual-sector level. In this section, we discuss these factors, and in the following section, we estimate the effect of variables that act as proxies for these factors on growth rates.

Drivers of growth are found on the supply and demand side. Productivity growth driven by innovations is the central determinant of production growth in the long run, as it typically leads to lower production costs (Asche 2008; Asche, Roll, and Tveterås 2009, 2012). In the next stage, this allows producers to expand production profitably even at lower prices. Shifts in market demand can also allow for growth,

through positive shifts in the market price at higher production levels.

In aquaculture, the following underlying factors that influence productivity and growth should be pointed out: (a) *innovation* in key areas; (b) *externalities* within aquaculture, particularly related to disease and fish health, and externalities to other sectors and users; and (c) exploitation of *internal and external returns to scale*. In the following section, we discuss each factor.

#### **Innovation in Key Areas**

During the 1970s and 1980s, the accumulated knowledge and innovations in aquaculture led to the introduction of more semi-intensive and intensive farming practices, and the production cycle was closed for an increasing number of



species. The control of the production process enabled a number of productivity-enhancing innovations to take place.

Examples of innovations that have generally increased productivity and sustainability in aquaculture and thus contributed to growth are:

- (1) feed and feeding equipment innovations that have contributed to more efficient conversion of feed to fish, lower local organic emissions, lower inclusion of fish oil and fishmeal, etc. (Tacon and Metian 2008);
- (2) vaccine innovations, which have reduced mortality, reduced use of antibiotics, etc.;
- (3) genetic innovations (breeding), which have contributed to more efficient conversion of feed to fish, increased growth rate, increased disease resistance, etc. (Gjedrem *et al.* 2012; Gjedrem 2012);

(4) farm infrastructure innovations, such as fish cages, monitoring equipment and information technologies embodied in them, which have increased robustness to exposed sea areas, reduced risk of fish mortality and escape, reduced labor intensity, etc. (Bostock *et al.* 2010).

Several aquaculture sectors, including salmon aquaculture, have evolved from a technological regime with a poor degree of control of many processes to one that can be described as approaching “biological manufacturing” (Asche *et al.* 1999; Tveterås 2002; Tveterås and Battese 2006). Technologically leading aquaculture sectors have moved from labor-intensive production where workers had few formal skills to production that is more capital-intensive and where computer hardware- and software-based technologies have replaced several

manual labor tasks. At salmon farms, for example, the fish, feeding, and environmental variables are monitored based on sophisticated information technologies. Labor input in the sector has become more specialized, with a much higher proportion of labor with a variety of specialized university education.

For carnivorous species, the supply of marine feed ingredients is restrained by limited wild fish stocks. Unless there are radical innovations in the production of algae or plant-based fish oil substitutes, several sectors must reduce inclusion rates for fish oil (and fish meal) further in order to grow (Tacon and Metian 2008).

In the innovation system related to aquaculture technology, government can play a central role through legislation,

policies, and funding. A technological innovation system is “a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilisation of technology.” The private actors in the innovation system include the farming companies and their suppliers, feed companies, equipment and software suppliers, pharmaceutical companies, etc. Universities and related research institutions can also be important actors as suppliers of trained labor and researchers, but also through the research and development (R&D) they have undertaken (Asche, Roll, and Tveterås 2012).

R&D is critical for many future radical innovations that are required to ensure growth. However, in aquaculture R&D, there is a high economic risk and a low degree of

appropriability of R&D benefits, that is, an inability to get sufficient private economic returns, for private firms investing in R&D (Asche, Roll, and Tveterås 2012). This represents a huge challenge in several areas and for some phases of technological development. A combination of private and public funding is therefore necessary, possibly supplemented by a government-mandated levy on the sales revenue of all firms in the sector for R&D funding. Without government intervention in the form of R&D subsidies, R&D levies, or other measures, the innovations that aquaculture industries' needs to achieve its potential for sustainable growth may not be realized.

#### **Externalities from Aquaculture Production**

Externalities are the effects of a firm's production on other firms, households, or other agents that are not fully internalized in the economic decision of the firm because it

does not have to cover the economic losses to others associated with the externality. These costs can be in the form of lost sales or increased unit cost for other firms, increased health costs for households, etc. Fish disease is an example of an externality in aquaculture. If a disease outbreak is caused by the production processes at a farm, the outbreak is an externality if other farms are affected by the disease outbreak and the farm does not have to cover the other farms' economic losses (Asche, Guttormsen, and Tveterås 1999; Asche, Roll, and Tveterås 2009). Figure 3.7 shows different types of externalities from a farm to other farms in the sector, and to other sectors and users.

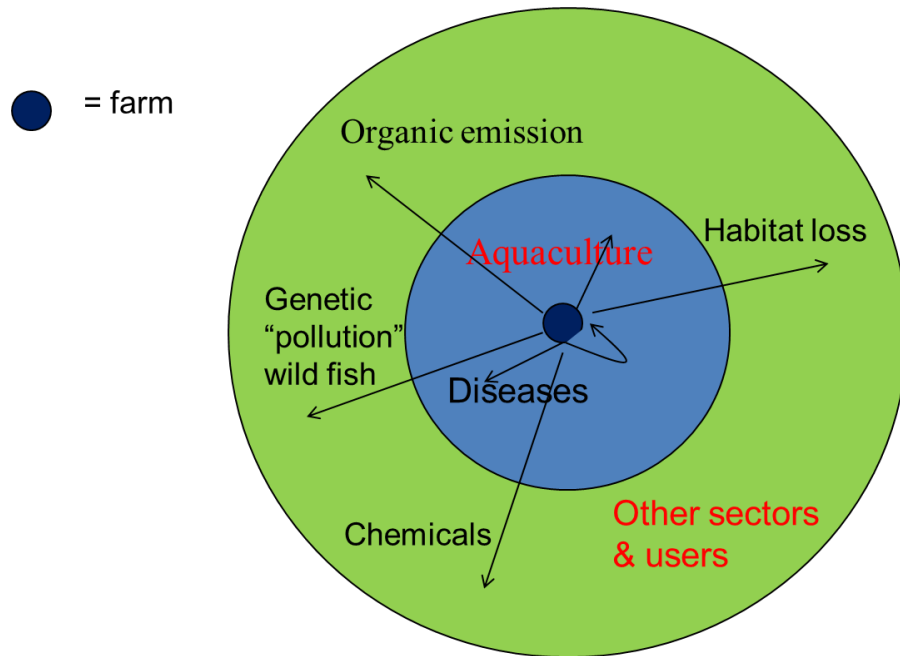


Figure 3.7. Externalities from Aquaculture

Many aquaculture sectors arguably have larger inherent negative animal disease externalities than agricultural livestock production, such as poultry and pig production, because production is less closed. Open cage production technologies are particularly exposed to disease externalities, depending on water flows, water traffic, density of farms, etc. Fish disease outbreaks have been of such a scale that in some

cases the outbreaks have almost wiped out production in entire sectors, for example, in Asian shrimp aquaculture. Furthermore, some sectors never recovered after disease outbreaks.

Externalities to other sectors and users can come in several forms, as suggested by Figure 3.7. Examples are organic emissions that pollute waters and change the nutrient balance, habitat loss (e.g., mangrove habitat), emission of toxic chemicals used to combat disease, escape of farmed fish that “pollute” the genetic pool of wild fish stocks, etc.

In aquaculture, externalities influence productivity and production (1) directly through diseases and other externalities that cause increased mortality or lower growth rates and (2) indirectly through public regulations and other policy



measures motivated by externalities. In theory, externalities provide a rationale for the government to introduce regulations or taxes to mitigate the externalities. However, in practice, designing appropriate measures is difficult for governments due to insufficient information about the mechanisms and magnitudes of the externalities. Measures to mitigate externalities can often fail because the effects are too small or too large, or because the measures have unintended effects.

Atlantic salmon farming is an example of a farmed species in which basically the same production technology is used across countries, but the government measures designed to mitigate externalities differ significantly (Gibbs 2009). The policy measures implemented in the main salmon producer countries have of course also been motivated by other policy objectives, which again have been influenced by the political power of different stakeholders. Policy measures that aimed to mitigate

externalities, or the absence thereof, have had significant effects on the development of production in salmon producer countries. For the United Kingdom (UK), Canada, and the United States (US), strict regulations have led to lower environmentally sustainable growth than could have been possible. In the more liberally regulated Chilean sector, the absence of proper regulations has led to a disease-driven decline in production since 2008 that could have been avoided (Asche *et al.* 2009).

One important aspect of innovation in the aquaculture sectors is that innovations often contribute to reducing the externalities in aquaculture. For example, new feed innovations often lead to less organic emissions and healthier fish that are less vulnerable to disease. New vaccines may reduce the need to use antibiotics or chemicals. In the future,

the combination of innovations and government regulations will determine the magnitude of externalities from aquaculture and the potential for sustainable growth.

#### **Exploitation of Internal and External Returns to Scale**

There are probably internal and returns to scale in aquaculture production in many sectors. *Internal returns to scale* are present when a 1% increase in input levels (labor, capital, feed, etc.) leads to more than a 1% increase in production, thus, when there are increasing returns to scale at a farm or in a firm the production costs per unit decrease because capital equipment, labor, etc., are used more efficiently. Several studies have found increasing internal returns are related to farm and firm size, for example, Tveterås (2002) and Asche, Roll, and Tveterås (2009) for salmon farming. Moreover, the studies suggest that innovations have increased the optimal scale of production, that is, the scale that provides the lowest

production cost per unit, implying that in order to be competitive farms and firms have had to increase their size over time.

*External returns to scale* are analogous to internal returns to scale, and are present when an increase in the scale of production in a sector, or related sectors, leads to increased productivity and reduced cost per unit. There are several sources of external returns to scale. One potential source is “thicker” markets for specialized inputs. For several types of capital equipment used by the aquaculture industry, full-capacity utilization requires that several or many farms demand their services. Moreover, the industry demands specialized expertise in management, export marketing, installation and maintenance of capital equipment, production monitoring, veterinary services, biology, etc. Providing

specialized producer services to the industry requires a certain minimum market size. An increase in the size of a country's aquaculture industry at some stages can lead to the provision of more productive specialized physical and human capital inputs that will increase productivity (Tveterås 2002).

Another source of external returns is increased knowledge spillovers. As the size of an industry or related industry increases, the scope for different arenas where firms and knowledge providers meet to exchange ideas and knowledge increases. Moreover, the opportunities for migration of human capital between firms, and between firms and surrounding institutions, increase with industry size. A larger industry also allows for capacity increase in education and research institutions oriented toward the industry.

External returns to scale that are geographically constrained to a country or a region are also called *agglomeration economies*, and they give rise to geographically concentrated clusters of firms and related institutions. According to the econometric estimates by Tveterås (2002) and Tveterås and Battese (2006) for salmon farming, significant productivity gains and cost savings are associated with localization in regions with a large salmon aquaculture industry, suggesting the presence of positive external returns to scale, that is, positive agglomeration externalities. Although the results of these studies are based on salmon farming data, other aquaculture sectors have similar characteristics that should give rise to increasing external returns to scale.

### **3.4. Aquaculture Sectors' Growth Patterns and Characteristics**

We will now move down to a more disaggregated aquaculture sector level and examine growth patterns. In the following, we define aquaculture sectors by species and country. For example, a sector could be turbot aquaculture in Spain or Atlantic salmon farming in Norway.

The story about global aquaculture sectors is not the story about the tree that grew into space. Few aquaculture sectors exhibit a steady increase in production over a longer time period. In contrast, the story about aquaculture sectors is often one of stagnation, decline, and even death. It is a story about economic risk in many dimensions (Tveterås 1999). The growth of aquaculture production shown in Figure 1 is the result of the growth and decline of individual sectors and the

entry and exit of sectors. Each year, a new cohort of aquaculture species and country sectors have entered the industry. Together with the existing aquaculture sectors, the new cohorts have contributed to the increase in total production.

Table 3.2 provides a summary of the production in the observed sectors in the database for only the last year for which data are available, 2010.<sup>2</sup> We see that there are a total of 1,909 sector observations in 2010. The average sector produced 41,000 metric tons, the smallest sector (close to) zero, and the largest sector 4.4 million metric tons.

When we compare different aquaculture environments for all species groups, we see in Table 3.1 (panel a) that the average marine sector produced 64,000 tons, almost twice as much as



the average freshwater sector with 34,000 tons, while the average brackish water sector produced only 20,000 tons. However, the relative sector sizes changes significantly when we focus only on fish and crustaceans in panel (b) of Table 1. The freshwater fish and crustacean sectors produced on average 35,000 tons, followed by the brackish water sectors with 20,000 tons, while the marine sectors on average produced only 14 tons. The biggest freshwater sector (grass carp in China) alone produced in 2010 as much as the total marine fish and crustaceans sectors, around 4.2 million tons. The difference in average sector size is so large that if there are external economies of scale at the sector level this may significantly influence the competitiveness of marine aquaculture sectors compared to freshwater and brackish water sectors.

**Table 3.1**

Production-output (MT) of All Aquaculture Sectors  
in the Last Data Year, 2010

	No. of sectors	Average sector output	Sector standard deviation of output	Smallest sector (min. output)	Largest sector (max. output)	Total output (in million MTons)
World	1,909	41,353	276,183	0	4,418,010	78.9
(a) Environments (all species)						
Brackish water	262	19,929	79,760	0.08	608,267	5.2
Freshwater	1,082	34,212	249,291	0	4,222,198	37.0
Marine	565	64,964	367,582	0	4,418,010	36.7
(b) Environments (fish and crustaceans only)						
Brackish water	225	20,447	79,055	0.08	608,267	4.6
Freshwater	1,044	34,685	253,599	0	4,222,198	36.2
Marine	288	14,415	62,378	0	927,876	4.2

In metric tons, except the last column.

Table 3.2 shows the average values of the characteristics of species and country sectors for only 2010. The first column shows the average production in a sector, which is the same as shown in Table 1. In the second column is the average production in all aquaculture sectors at the country level. For

the entire world, the average country level production in 2010 was 2.7 million MT, an average that was considerably influenced by China. Marine sectors reside in countries with a higher average total aquaculture production (3.8 million tons) than freshwater and brackish water sectors (1.9 and 1.3 million tons, respectively).

Another interesting figure is the ratio of production in 2010 relative to the sector's historical maximum production. The ratio gives an indication of the riskiness of aquaculture production and bottlenecks that each sector has faced during its lifetime. If an aquaculture sector grows from year to year with minor disruptions, then the ratio will be one or close to one in 2010. According to Table 2, the world's freshwater sectors average ratio of production in 2010 relative to the historical maximum production was 64%, while marine and

brackish water sectors had a slightly lower average ratio of 61%.

**Table 3.2**

Average Values of Fish and Crustacean Sectors in 2010

	Production in sector (MT)	Production of fish and crustacean sectors in country (MT)	Production in all sectors in country (MT)	Production 2010/historical maximum production	Age of sector in years
<b>Environments</b>					
Brackish water	20,447	501,955	1,348,387	0.61	20.6
Freshwater	34,685	796,376	1,933,201	0.64	19.8
Marine	14,415	1,104,302	3,799,779	0.61	15.3
<b>Marine sectors by regions and countries</b>					
Africa	393	6,555	1,659	0.57	12.3
Asia	14,827	2,648,623	8,219,711	0.64	15.1
Europe	13,441	89,916	182,062	0.58	15.7
Latin America	27,334	131,196	196,374	0.61	13.6
North America	22,717	215,355	328,212	0.68	19.5
EU27	4,785	52,306	158,284	0.52	16.3
Developing	14,052	1,825,812	6,440,931	0.63	13.2
Developed	14,903	110,149	256,771	0.60	18.1
China	60,785	24,700,000	47,800,000	0.84	9.1
Norway	167,654	1,006,009	1,008,010	0.74	25.8

Next, we examine the marine fish and crustacean sectors by global region. As shown in Table 3.2, the largest average sector in 2010 was in Latin America with 27 thousand metric tons (TMT), followed by North America (23 TMT), Asia (15 TMT), and Europe (13 TMT). Within Europe, the European Union (EU27) has significantly smaller sectors, with an average sector size of 4,785 MT. In fact, the European average is driven up by Norway (at the bottom of the table). China has an average sector size of 61 TMT. The average production ratio for the Chinese sector in 2010 relative to the historical maximum production was 84%.

As shown in Table 3.2, there are small differences between the average size of the sectors in developing and developed countries, with 14 TMT in developing countries and 14.9 TMT in developed countries. Developing countries' marine

aquaculture sectors are surrounded by a bigger overall aquaculture sector than developed countries and are younger.

### **3.5. Econometric Analysis of Growth Rates**

Next, we analyze the factors that influence production growth rates in aquaculture sectors using econometric panel data models based on the FAO Fishstat dataset of species- and country-level aquaculture sectors. We test the relationships between the aquaculture sector growth rates and the following factors: (a) internal scale of the sector, (b) scale of other aquaculture sectors in the same country, (c) age of the sector, and (d) observation year.

These models should not be interpreted as causal economic models. However, for the (a) internal scale of the sector and (b) the scale of other aquaculture sectors in the same country

we may capture the effects of increasing or decreasing external returns to scale. Increasing returns to scale should contribute to higher growth rates; if the returns to scale are decreasing, then they should contribute to lower growth rates. Sources of increasing external returns may be increased knowledge spillovers, and increased competition and emergence of specialized highly productive input suppliers. However, negative (congestion) externalities in the form of diseases, organic emissions, habitat destruction, etc., may be sources of decreasing external returns to scale.

Broader returns to scale associated with the size of other aquaculture sectors may be related to increasing public aquaculture-specific infrastructure that is made possible by the total aquaculture in the country. This aquaculture-specific infrastructure may be in the form of public education

institutions, R&D institutions, extension services, specialized private input suppliers, etc.

Sector age is measured from the first year production is observed, and can be a proxy for learning and innovation in the sector. One question is whether there is more innovation and learning during the early years of an aquaculture, and thus a greater effect on growth.

Time measured by year is included to account for unobserved factors that may influence the growth rate development over time. One unobserved factor may be the development of the innovation rate, or the rate of exogenous technical progress, in aquaculture over time. Another factor may be change in the scarcity of inputs over time, for example, land area, sea area,



marine feed input sources, etc. Finally, time may also account for shifts in consumer demand for seafood from aquaculture.

Different specifications of the following econometric growth model are estimated:

$$\begin{aligned} \ln Y_{it} - \ln Y_{it-1} = & \mu_i + \beta_{dy1}(\ln Y_{it-1} - \ln Y_{it-2}) + \beta_{y1} \ln Y_{it-1} + \beta_{y12}(\ln Y_{it-1})^2 \\ & + \beta_{e1} \ln E_{it-1} + \beta_{e12}(\ln E_{it-1})^2 + \beta_{aa} \text{age} + \beta_{aa} \text{age}^2 + \beta_{tt} + \beta_{tt}^2, \end{aligned}$$

where  $i$  = the aquaculture sector subscript (defined by species and production country),  $t$  = year,  $Y$  = production volume in metric tons,  $E$  = production volume in other aquaculture sectors in same country in metric tons, and  $age$  = the age of the sector in years.

In one model specification, we allow for environment-specific estimates of the slope parameters, to test for structural

differences between the marine, freshwater, and brackish water sectors. In some specifications, the time trend variable is replaced by year dummy variables to allow for more flexible time-specific effects. The heterogeneity of the sector-specific effects  $\mu_i$  are also tested using fixed sector-specific effects. The models are estimated with robust standard errors. We also test both weighted models using production volume as weight, in order to allow larger sectors to influence estimates more than smaller sectors. Due to space considerations, we present only the estimated marginal effects of the primary variables of interest from our estimated models. The full econometric results are available from the authors upon request.

Table 3.3 provides the estimated partial effects from an econometric model specification where the marine sector is the base sector, where we have interacted all the slope

coefficients with freshwater and brackish water dummy variables, and have environment-specific intercepts. An F-test of all the slope coefficients and intercepts associated with the freshwater and brackish water sectors confirms environment heterogeneity at the 1% level, with a test statistic of  $F(10,37071) = 13.84$ . The estimated marginal effects on the growth rate are obtained by partial derivation of the estimated model for the explanatory variables. We see for this particular specification that the effect of sector size on the growth rate is significantly negative for all environments. The size of the other aquaculture sectors in the same country has a significantly positive effect on the growth rate. A mixed effect is found for the age of the sector, as it is zero for marine sectors and has a significantly negative effect on the freshwater and brackish water sectors. Finally, after having controlled for

these factors, the model predicts that the growth rate will increase over time for all environments.

**Table 3.3**

Estimated Mean Long-Run Marginal Effects on Growth Rate from a Pooled Model Allowing for Environment Heterogeneity in Slope Coefficients and Intercept

Model	Marine		Freshwater		Brackish water	
Sector size	-0.3666	***	-0.2677	***	-0.2510	***
Size of other aquaculture sectors	0.0426	***	0.0293	***	0.0302	***
Age of sector	0.0003		-0.0026	***	-0.0026	**
Time	0.0016	*	0.0020	***	0.0034	***

Number of observations: N = 37,091. Explanatory power: R-squared = 0.28. \* Significant at the 10% level. \*\* Significant at the 5% level. \*\*\* Significant at the 1% level.

Next, we focus on marine sectors only and estimate different econometric model specifications. Table 3.4 presents the estimated long-run marginal effects on the growth rate from econometric models evaluated in the sample mean observation, together with other information about the model

specifications. Two of the models (2 and 3) have sector-specific fixed effects. According to the  $\rho$  estimate, the sector-specific effect explains much of the total regression variance  $\sigma_u^2 + \sigma_e^2$  in models 2 and 3. Models 4 and 5 have country dummy variables and species dummy variables, respectively. Compared to Model 1, the inclusion of these dummy variables is firmly supported by conventional F-test statistics.

All estimated models 1–5 provide a significantly negative relationship between own sector size and the sector's growth rate. However, the marginal effect of own size is much lower for models 2–4, which have sector-specific or country-specific fixed effects, than for models 1 and 5. There is a positive estimated relationship between the size of other aquaculture sectors in the same country and the sector's growth rate. The relationship between the age of the sector and its growth rate

is less clear, as the estimated models provide different signs. Finally, the relationship between time and the growth rate is zero, except for Model 2, which provides a significantly positive marginal effect. However, the estimated time-specific effects of Model 3 predicted a significant decline in the growth rate over time.

**Table 3.4**

Estimated Mean Long-Run Marginal Effects on Growth Rate from  
Econometric Models on Marine Sectors

Model	1	2	3	4	5
Sector size	-0.533 ***	-0.151 ***	-0.140 ***	-0.115 ***	0.575 ***
Size of other aquaculture sectors	0.033 ***	0.128 **	0.074 *	0.037 *	0.027 ***
Age of sector	0.002	-0.018 ***	0.071 ***	0.006	0.003
Time	0.001	0.042 ***	N/A	0.002	0.000
Sector-specific effect	None	Fixed	Fixed	None	None
Time-specific effect	None	None	Fixed	None	None
Other dummy variables	None	None	None	Country	Species
Weight	Prod.	Prod.	Prod.	Prod.	Prod.
$\sigma_u$	N.A.	1.147	1.117	N.A.	N.A.
$\sigma_e$	N.A.	0.604	0.557	N.A.	N.A.
$\rho = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_e^2}$	N.A.	0.782	0.801	N.A.	N.A.
N	10986	10986	10986	10986	10986
R-squared	0.403	N.A.	N.A.	0.5393	0.5393

\* Significant at the 10% level. \*\* Significant at the 5% level. \*\*\* Significant at the 1% level.

### 3.6. Concluding Remarks

Contrary to high expectations from policy makers and others, marine fish and crustacean aquaculture still represent only around 10% of the total global production. Furthermore, the growth rate of marine fish and crustacean aquaculture seems to be declining, even more than for total aquaculture.

We have seen that the growth of aquaculture has partly been associated with the introduction of new species and the entry of new producer countries. Measured by the Herfindahl index, this has led to lower concentration levels in the species and country dimensions. Still, a limited number of species and countries continue to represent the bulk of global production. Many of the species are produced in very small quantities and with little growth. One may well ask what mechanisms lead to



introduction of new species, and what economic returns come from many of the species produced in small quantities.

In the econometric analysis, we failed to find overwhelming evidence of an exogenous decline in the growth rate over time for marine sectors after we controlled for other factors. The results suggest that the growth rates for aquaculture sectors in general and marine sectors in particular may be related to external economies of scale and learning effects.

The estimates from our econometric model specifications on marine sectors can be summarized as follows: The scale of the sector is generally associated with a significantly negative marginal effect on the growth rate. The scale of other aquaculture sectors in the same country tends to be associated with a significantly positive marginal effect on growth rates.

The age of the sector has an ambiguous marginal relationship with its growth rate. After having controlled for the other factors, the growth rate tends to be stable over time.

Increasing production in coastal regions tends to cause increased negative external effects in the form of fish diseases and different forms of pollution unless the aquaculture industry innovates and improves practices that mitigate the externalities (Bostock *et al.* 2010; Anh *et al.* 2010). In sum, marine aquaculture production must continue the transition from a technological regime with a limited degree of control of many processes to one that can be described as approaching “biological manufacturing.” This shift must be driven by innovations in key technologies. Innovations will allow for productivity growth, and be translated into declining

production costs, historically the central cause of the global growth of aquaculture production.

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Endnotes

1. For instance, in brackish water aquaculture, production of tiger prawns has decreased, and white-leg prawns have increased over the last few decades. In freshwater aquaculture, the largest species (the silver carp or white amur) increased in 2010 compared to the common carp, which was the largest species in 1990. Similarly, in marine FC aquaculture, the Japanese sea bass, which was not registered in 1990, has been introduced.

2. Appendix A shows the same summary statistics for all sector observations from 1950 to 2010.

### Appendix A

Production of All Aquaculture Sector Observations, 1950–2010,  
Metric Tons

	No. of sectors	Average sector	Sector standard deviation	Smallest sector (min.)	Largest sector (max.)
World	38,308	15,686	126,035	0	4,222,198
Environments					
Brackish water	6,248	9,727	38,898	0	608,267
Freshwater	25,766	18,942	151,120	0	4,222,198
Marine	6,294	8,268	39,469	0	927,876



## **Paper 4: Consumer Product Perceptions and Salmon Consumption Frequency: The Role of Heterogeneity Based on Food Lifestyle Segments**

### **Abstract**

Seafood consumers are vastly heterogeneous in terms of their knowledge, confidence, and perceptions about seafood. This article examines the relationship between consumer perceptions (healthiness, value for money, and convenience) and salmon consumption frequencies while modeling unobserved consumer heterogeneity by segmenting consumers based on their food-related lifestyle. We employ latent class analysis (LCA) that embeds the structural equation modeling (SEM) to ensure the latent nature of both the consumer segment and the food lifestyle measures are properly accounted for. The analysis is applied to five European countries (United Kingdom, Germany, France, Russia, and Sweden). We contribute to the literature by providing new insights into how food lifestyle may influence the salmon consumption behavior by highlighting the differences among food lifestyle segments in different countries.

### **4.1 Introduction**

Although seafood has been used as an important protein source in most cultures throughout history, a widespread increase in seafood consumption has occurred recently as a

result of expanding aquaculture production, improved distribution technologies, and increased global trade and competition (Asche 2008; Tveterås et al. 2012; Sorvig and Tveterås 2014). Atlantic salmon provides a good example of a globalized aquaculture industry, with a significant product presence in most modern consumer markets through integrated supply chains and product development partnerships (Kvaløy and Tveterås 2008; Olson and Criddle 2008; Asche et al. 2013). The main reasons for increased production is productivity growth (Vassdal and Holst 2011; Roll 2013; Asche and Roll 2013; Asche, Guttormsen, and Nielsen 2013), more efficient supply chains (Asche, Roll and Tveterås 2007; Larsen and Asche 2011, Asche et al. 2014), and increased demand. There are a number of demand studies focusing on economic factors like prices and income (Asche, Bjørndal, and Gordon 2007; Xie and Myrland 2011), while

other studies investigate the effects of marketing (Kinnucan and Myrland 2007). The only paper quantifying demand growth is Asche et al. (2011), who find an average per annum demand growth of 7.6 % over a 14-year period. However, little attention has been given to individual consumer behavior, which at the end is responsible for this increased demand.

Due to the rapidly changing market environments, seafood consumers are increasingly heterogeneous in terms of their knowledge, confidence, and perceptions about seafood. As such, understanding consumer heterogeneity is a central issue when analyzing consumers' marketplace behavior, estimating and forecasting demand for various goods and services, and designing marketing strategies. In a variety of empirical economic studies, consumer heterogeneity is accounted for a priori by inclusions of demographic characteristics in either

demand equations or utility functions (Boxall and Adamowicz 2002). However, it is often difficult to determine the nature of heterogeneity a priori, or the nature of the heterogeneity can be based on unobserved variables.

Positive product perceptions, for example, are commonly linked to higher purchase intentions (e.g., Hansen and Sallis 2011). Modeling a direct linkage between a bundle of perceptual predictor variables and purchase or consumption frequencies, e.g., through regression analysis, could very well indicate significant effects, but this type of model would not account for the possibility of the relationship varying between different groups of consumers. For example, it is possible that the perceived convenience of a product may affect its purchase, but the size and the significance of the effect can vary among consumers with different preferences for

convenience. Then, the marginal change in perceived convenience can generate non-constant effects on purchasing behavior. In such an instance, failing to account for underlying heterogeneity might produce biased estimations (Jedidi, Jagpal, and DeSarbo 1997).

If, on the other hand, people hold similar perceptions regardless of their consumption behavior, perceptual differences would not explain the heterogeneous market behavior among consumers. In these cases, looking only at a direct measure of product perception and consumption of a specific product may fail to capture the important underlying effects. For example, Brunsø et al. (2009) report that consumers, in general, hold the perception that fish is healthy. However, it is found that positive perceived healthiness alone does not affect purchase behavior; a positive effect of

perceived healthiness of fish on purchasing behavior is only found when it interacts with one's interest in healthy eating (Pieniak et al. 2008).

An important insight from past research is to consider the heterogeneity in latent cognitive factors that interact with perceptions to affect purchasing behavior. Even so, the unobserved nature of such underlying constructs is a research challenge, as is modeling a priori how these constructs work. One useful framework that can link general cognitive values to specific food choices is the food related lifestyle (FRL) instrument (Grunert, Brunsø, and Bisp 1997; Brunsø, Scholderer, and Grunert 2004). Unlike other ad hoc measures of lifestyle, FRL is rooted in the means-end chain theory in the consumer behavior literature (Olson and Reynolds 1983; Peter and Olson 1993), and is tailored for a lifestyle related to food

(Grunert, Brunsø, and Bredahl 1998). In addition to its theoretical basis and applicability to food-related behavior, another appealing feature of the FRL is that it can be implemented cross culturally (e.g., Scholderer et al. 2004). As seafood is highly traded internationally, it is common for seafood companies to deal with international consumer markets with different cultural and social norms. Thus, adopting a universal framework, such as FRL, is useful to gain insights to both individual and country-level heterogeneity. FRL has been applied in various studies and has been found to capture heterogeneity in consumers' food related-behavior (e.g., de Boer et al. 2004; Wycherley, McCarthy, and Cowan 2008; Pérez-Cueto et al., 2010; Zepeda and Nie 2012).

In this article we consider three consumer perceptions; healthiness, value for money, and convenience and investigate

the effects these perceptions have on salmon consumption frequencies. While doing so, we introduce the FRL-measures as an intervening factor that can link the abstract cognitive values to specific consumption decisions. Then we formulate food lifestyle consumer segments and empirically test if the product perception-consumption frequency relationships differ among segments. The use of latent class analysis (LCA) that embeds the structural equation model (SEM) framework ensures that the latent nature of both the consumer segments and the food lifestyle measures are properly accounted for (Jedidi, Jagpal, and DeSarbo 1997). Furthermore, the analysis is applied to five European countries (United Kingdom, Germany, France, Russia, and Sweden). Thus, we contribute to the literature by providing new insights on how “food lifestyle” may influence salmon consumption behavior by highlighting the differences among food lifestyle segments in



different countries. The theoretical point of departure, our suggested model, and the empirical procedures undertaken are presented in the succeeding paragraphs. Finally, the results are presented and discussed.

#### **4.2. Previous research and conceptual framework**

Our point of departure is the basic notion found in most marketing models that aim at predicting consumption. That is, consumers base their decisions on (amongst others) their perceptions of the products in question (Schiffman, Kanuk, and Hansen 2011). This assumption, while simply expressed, implies that the product perceptions that actually determine choice behavior might, and usually will, vary between product categories, usage contexts, consumer groups, and the basic underlying motivation on which the behavior rests. Identifying relevant product perceptions are of utmost importance to any marketing manager. For food, in general, and seafood, in

particular, we argue that for the research questions addressed here, consumer perceptions of healthiness, value, and convenience are central.

First, healthiness and healthy eating have received an enormous amount of attention among consumers as obesity, cardiovascular diseases, and type two diabetes have unfolded in increasingly larger numbers (e.g., Mozaffarian and Rimm 2006). Hence, academic researchers, from fields as diverse as clinical nutrition and economics, and consumers, have joined forces to find solutions to health problems caused by what and how much we eat. According to Drescher et al. (2009:687), household production theory can be applied to explain consumer intentions to eat healthy as “it is assumed that households maximize a combined utility function to produce final goods such as own health or health of the family

members.” Drescher et al. further describes these final goods as ‘commodities’ that provide utility. Food is one of the inputs required to produce desired level of the health commodity. Thus, we can assume that a consumer is motivated to judge the healthiness of the food eaten regardless of whether s/he suffers from diet-related health issues. That being said, consumers shopping for food are typically not buying a single product, but a basket full of groceries (Staus, 2011). Hence, the judgment is multidimensional where some foods are purchased based on a health motive (salad for tomorrow’s lunch), while others are bought to satisfy other needs (ingredients for the evening’s romantic dinner).

Related to our research context, we argue that fish, in general, and thus also salmon, are associated with healthiness because of a lack of “bad” fat (saturated fat) and the richness of “good”

fat (Omega-3). Moreover, healthy eating habits often result from what a product does not contain rather than what it does. For example, drinking water instead of soda might primarily be motivated by all the sugar that you will *not* ingest—not the nutritional content of water. Drawing on this, we suggest that salmon is a product that consumers might associate with healthiness because it is healthy in itself (e.g., contains Omega 3) and because it is an alternative to other products judged to be unhealthy (e.g., “Too much red meat is not good for me, so today I’ll have salmon.”). Consequently, we assume perceived healthiness to be positively related to the consumption frequency of salmon.

Second, we believe that the perceived value of a salmon product will increase consumption frequency. Customer-perceived value has been extensively described in the

literature (e.g., Eggert, Ulaga, and Schultz 2006; Flint, Woodruff, and Gardial 2002; Gassenheimer, Houston, and Davis 1998; Wilson 1995), and typically, most definitions and conceptualizations focus on the economic worth of tangible outcomes. One such conceptualization conceives of value as the economic worth of a bundle of physical goods and services that is exchanged for some price (Newman 1988). Others suggest a broader conceptualization and define value as “... the worth in monetary terms of the economic, technical, service and social benefits a customer receives in exchange for the price it pays for a product offering” (Anderson and Narus 1990:5). Definitions of this kind clearly state that value is a monetary issue. According to Hansen, Samuelsen, and Silseth (2008), it is important to differentiate between the means contributing to value creation and the perception of value as an end. They suggest that “Value” (the end) is inherently a

tradeoff assessment of the type “what you get for what you give,” (p. 207) and define value as the benefits received by the customer divided by the resources sacrificed to acquire them. Although the perception of value itself might result from other sources rather than purely rational attributes (e.g., extrinsic cues), decisions to repeatedly consume a (food) product are probably based on rational satisfaction judgments related to value (Gassenheimer, Houston, and Davis 1998). Hansen and Sallis (2011) found value perceptions to have a significant positive effect on purchase intentions for Vietnamese *Pangasius* in Norway. Moreover, Hansen, Samuelsen, and Silseth (2008) found customer perceptions of value to be negatively related to their search for alternatives, a behavior logically adverse to the intentions to continue consumption of a product. Arguably, perceptions of value are important for an initial purchase decision, the decision to continue consuming

a product, and an exit decision. Based on this, the second predictor variable included in our model is that of perceived value, which we believe will positively influence salmon consumption frequency.

Third, we believe that convenience is positively related to the frequency of salmon consumption. Convenience is a concept consisting of two primary dimensions – time and effort (or energy) (Marquis 2005; Candel 2001). Time refers to time pressure or lack of time, and both will motivate consumers to choose more convenient paths of behavior. Effort, or energy, concerns both the mental and physical effort needed to acquire some end goal related to the product in question (e.g., planning and preparing a meal). According to Candel (2001), convenience is an important determinant for food-related behavior among consumers, and previous studies have found

that preferences for meals and snacks (Rappoport et al. 1993), beverage packages (Van Dam and Van Trijp 1994) and meat (Andersen and Shugan 1991) are all related to convenience perceptions. We find no reason as to why similar relationships should not also hold for the consumption frequency of salmon. Preparing a meal from a whole salmon might take time and require effort, depending on consumer skill and product knowledge, while preparing a meal from a boneless salmon steak requires less effort. Hence, we suggest that salmon consumption frequency is positively affected by convenience perceptions.

Finally, the three predictor variables presented here are all related to the product, consumer, and consumption experience in conceptually different ways. Starting with value, this variable may be termed as an important part of the cost-benefit



analysis, or cost-benefit comparison, that consumers are able to perform when choosing between alternative foodstuffs. As such, value is a product feature related to economic costs. Convenience, on the other hand, says something about the ease with which consumers can make use of the product. We may, in other words, say that convenience is connected to the perception of time and effort needed to benefit from the product. Healthiness is a body-oriented issue primarily related to perceptions of physical risk and/or feelgood, depending on whether consumers view the healthiness dimension from an approach or an avoidance perspective (Hoyer and MacInnis 2008). However, the preceding description portrays the fact that the three product-related perceptions under study here are based on different product attributes, characteristics, or consumption outcomes, and thus cover a wider range of judgments on behalf of the consumer.

“Lifestyle” and related concepts have been explored in the literature as factors that can contribute to explaining consumer behavior (e.g., Myrland et al. 2000; Olsen et al. 2007; Pieniak et al. 2008; Brunsø et al. 2009). Different lifestyle measures have been used for segmentation analysis (as discussed in Steenkamp and Ter Frenkel [2002]), such as those based on number of activities, interests, and opinions (AIO) and instruments like values, attitudes and lifestyles (VALS). However, these measures have also been criticized for lack of theoretical basis (Scholderer et al. 2004). There has been an effort to capture lifestyle with more theoretical rigor, and Grunert and colleagues developed the FRL instrument based on a means-end chain approach (Grunert, Brunsø, and Bisp 1997; Brunsø, Scholderer, and Grunert 2004). In FRL, lifestyle is hierarchically structured with more trans-

situational personal values at the top level, and more situation-specific input, such as product perceptions, at the bottom. Lifestyle is defined as “an intervening system of cognitive structures that link situation-specific product perceptions to increasingly abstract cognitive categories, and finally personal values” (Scholderer et al. 2004). This measure is highly relevant, as it was developed specifically to segment consumers based on their preferences regarding food (Zepeda and Nie 2012). The FRL has been used in various food related studies in European countries, as well as in Asia and Oceania, and has been validated and found to be a consistent and reliable measure for latent lifestyle characteristics (Scholderer et al. 2004).

One of the leading methodologies to account for unobserved heterogeneity, such as one based on latent food lifestyle

measures, is the latent class model (LCA), where heterogeneity is structured with a discrete distribution (Aitkin and Rubin 1985)<sup>1</sup>. In LCA, the population is divided into subgroups, and in the most general case, models of interest are estimated for each subgroup in which parameters are not restricted between subgroups. In addition, the group membership probability is also estimated, so that an individual has a certain probability to belong to each segment. This feature of LCA makes it different from the mixture model where continuous, instead of discrete, distribution is employed to describe the nature of the heterogeneity, and from cluster analysis, in which segment membership is deterministic. The act of segmenting consumers into a finite number of segments makes it easier to *explain* the nature of heterogeneity compared to the mixture model (Boxall and Adamowicz 2002). Compared to cluster analysis, researchers can utilize

familiar statistical indicators and various information criteria, which makes it easier to determine the appropriate number of segments.

Another advantage of LCA is the flexibility in specifying the segmentation base. A fairly common situation is when researchers wish to use unobserved (latent) variables as a segmentation base; for example, lifestyle, personality, or other specific traits. In the case of lifestyle, an individual's choice of lifestyle would affect his/her food choices; however, lifestyle is a concept that does not have a direct measurement. Instead, researchers may observe *indicators* that arise from the latent concept of lifestyle. One can use these indicator variables to construct a latent variable lifestyle. However, indicators are measured with errors. Accounting for measurement errors, while combining multiple indicators to

create a latent variable and examine the structural relationship among latent (and observed) variables, is a well-developed method in the SEM literature (Bollen 2010). A combination of LCA with embedded SEM (also called finite mixture SEM) provides a powerful, flexible tool for researchers who wish to investigate underlying consumer heterogeneity arising from unobserved factors (Jedidi, Jagpal, and DeSarbo 1997).

#### **4.3. Survey**

A web-based survey was administered during late 2011 in key European markets for Norwegian salmon (including the UK, France, Germany, Russia, and Sweden). The survey was administered online by Survey Sampling International, Inc. to their panel members, using age and gender as stratifying criteria to mimic the general population. Invitations were sent to their panel members until we obtained the target sample size of 500 completed responses from each country. The survey

questionnaire contained questions soliciting their food related lifestyle, product perceptions, and consumption frequencies, as well as demographic information. Some of the basic summary statistics from the sample are shown in table 1 (appendix).

The original FRL instrument includes 23 dimensions, each measured with 3 statements, resulting in total of 69 statements. Since our purpose is to build on FRL, rather than replicate it, we selected seven dimensions that we deemed more relevant to seafood consumption behavior.<sup>2</sup> The selected dimensions are *freshness, health, taste, cooking methods, convenience, importance of product information, and price/quality relations*. The indicator questions for each of these dimensions are shown in the Appendix. The mean scores of these dimensions, by country, are provided in table 2. The values

range from one to seven, where seven indicates a strong agreement with the statement.

**Table 2. Mean Scores of Food Lifestyle Dimensions by Country**

Food Lifestyle Dimensions	Country	Mean	Std. Deviation
Importance of product information (PI)	UK	4.89	1.30
	Russia	5.36	1.32
	Germany	4.86	1.36
	France	4.72	1.27
	Sweden	4.72	1.34
	Total	4.91	1.34
Health (HL)	UK	4.93	1.29
	Russia	5.89	1.28
	Germany	5.35	1.11
	France	5.09	1.27
	Sweden	4.78	1.39
	Total	5.21	1.33
Price/quality relationship (PQ)	UK	5.78	.92
	Russia	6.09	1.06
	Germany	5.77	1.02
	France	5.52	1.08
	Sweden	5.44	1.07
	Total	5.72	1.05
Taste (TS)	UK	5.19	.82
	Russia	5.05	1.10
	Germany	5.43	.88
	France	5.18	.87
	Sweden	5.03	.83
	Total	5.17	.91



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Freshness (FR)	UK	5.43	1.12
	Russia	6.00	1.09
	Germany	5.41	1.28
	France	5.18	1.24
	Sweden	5.36	1.25
	Total	5.47	1.23
Interest in cooking (CK)	UK	4.64	1.28
	Russia	4.12	1.39
	Germany	4.36	1.25
	France	4.81	1.25
	Sweden	4.83	1.28
	Total	4.56	1.32
Convenience (CV)	UK	3.44	1.30
	Russia	2.91	1.26
	Germany	3.31	1.25
	France	3.85	1.07
	Sweden	2.55	1.07
	Total	3.21	1.28

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Product perceptions about salmon are asked with a question “how would you rate salmon in terms of these criteria: "healthiness," "value for money," and "convenience" on a scale from 1 (extremely poor) to 7 (superior).” The consumption frequency question is phrased as “How often do you eat salmon at home?” and respondents select one from the

categories “about once a week or more,” “about once in two weeks,” “about once a month,” “every second month,” “2 to 5 times a year,” and “less than once a year or less.” The consumption frequency categories are then converted into the annual consumption frequency using “about once a week or more = 55,” “about once in two weeks = 27.5,” “about once a month = 12,” “every second months = 6,” “2 to 5 times a year = 3.5,” and “less than once a year or less = 1.” The summary of the product perception ratings and consumption frequencies are given in table 3.

***Table 3. Variable Summary Statistics of Product Perception and Consumption Frequency***

Country		Mean	Std. Deviation
UK	Annual Consumption Frequency	15.44	18.25
	Perceived healthiness	5.69	1.559
	Perceived value for money	3.98	1.651
	Perceived convenience	4.68	1.688
Russia	Annual Consumption Frequency	14.64	15.26
	Perceived healthiness	5.96	1.395
	Perceived value for money	4.07	1.687
	Perceived convenience	4.92	1.673
Germany	Annual Consumption Frequency	14.09	15.58
	Perceived healthiness	5.65	1.487
	Perceived value for money	4.73	1.634
	Perceived convenience	4.63	1.658
France	Annual Consumption Frequency	16.34	16.49
	Perceived healthiness	5.21	1.554
	Perceived value for money	3.8	1.497
	Perceived convenience	4.7	1.487
Sweden	Annual Consumption Frequency	21.83	19.19
	Perceived healthiness	6.1	1.39
	Perceived value for money	4.27	1.647
	Perceived convenience	5.05	1.587

#### 4.4. Methodology

The estimation model consists of two parts. One part estimates the latent class based on the latent food lifestyle measures. The other part estimates the auxiliary regression to investigate the relationship between product perceptions and purchase frequencies. Denote  $\pi_k$  as the class membership probability such that  $\sum_{k=1}^C \pi_k = 1$ , where  $C$  is the number of classes. This probability is estimated in LCA based on the responses to the food lifestyle questions (shown in the Appendix). The responses range from one (strongly disagree) to seven (strongly agree); thus, we treat them as ordered categorical responses.

Given the food lifestyle class, the individual  $i$ 's response to the  $j^{\text{th}}$  indicator ( $j = 1, \dots, q$ ) for  $k^{\text{th}}$  latent class has the observation mechanism:

$$\begin{aligned}
 x_{ijk} &= 1 \text{ if } x_{ijk}^* \leq \tau_{jk1}, \\
 &= 2 \text{ if } \tau_{jk1} < x_{ijk}^* \leq \tau_{jk2}, \\
 &\vdots \\
 &= 7 \text{ if } x_{ijk}^* > \tau_{jk6},
 \end{aligned} \tag{1}$$

where  $x_{ijk}^*$  is the unobserved continuous latent variable underlying the observed ordered categorical responses, and  $\tau$ 's are the unknown threshold parameters. The observed indicators are typically assumed to have a distribution:

$$\mathbf{x}_{ik}^* \sim \text{MVN}(\boldsymbol{\mu}_k^*, \boldsymbol{\Sigma}_k^*), \tag{2}$$

where  $\boldsymbol{\mu}_k^*$  is a  $q \times 1$  vector of means of the latent variables, and  $\boldsymbol{\Sigma}_k^*$  is the  $q \times q$  covariance matrix. The observed responses alone do not permit the identification of both threshold parameters and distribution parameters,  $\boldsymbol{\mu}_k^*, \boldsymbol{\Sigma}_k^*$  so some form of restrictions need to be imposed.

The measurement model is specified given the latent response variables:

$$x_{ijk}^* = v_{jk} + \boldsymbol{\lambda}'_{jk} \boldsymbol{\xi}_{ik} + \delta_{ijk}, \quad (3)$$

where  $v_{jk}$  is the latent intercept,  $\boldsymbol{\lambda}_{jk}$  is an  $r \times 1$  vector of parameters that relates the  $r$  latent concepts to the  $j^{\text{th}}$  observed response for the  $i^{\text{th}}$  individual in the class  $k$ ,  $\boldsymbol{\xi}_{ik}$  is the  $r \times 1$  vector of the  $i^{\text{th}}$  individual's level of the latent constructs, and  $\delta$  is the measurement error. It is typically assumed that  $\boldsymbol{\xi}_{ik} \sim \text{MVN}(\boldsymbol{\kappa}_k, \boldsymbol{\Phi}_k)$  and  $\boldsymbol{\delta}_{ik} \sim \text{MVN}(0, \boldsymbol{\Theta}_k)$  where  $\boldsymbol{\kappa}_k$  is an  $r \times 1$  vector of factor means,  $\boldsymbol{\Phi}_k$  is an  $r \times r$  factor covariance matrix, and  $\boldsymbol{\Theta}_k$  is an error covariance matrix. It is also assumed that the latent constructs,  $\boldsymbol{\xi}$ , and error terms are uncorrelated.

This formulation leads to the structure:

$$E(\mathbf{x}_{ik}^*) = \boldsymbol{\mu}_k^* = \mathbf{v}_k + \boldsymbol{\Lambda}_k \boldsymbol{\kappa}_k \quad (4)$$

and

$$\text{Cov}(\mathbf{x}_{ik}^*) = \boldsymbol{\Sigma}_k^* = \boldsymbol{\Lambda}_k \boldsymbol{\Phi}_k \boldsymbol{\Lambda}'_k + \boldsymbol{\Theta}_k. \quad (5)$$

Again, not all the parameters are identified and restrictions are needed for identification (Millsap and Yun-Tein, 2004).

With the normality assumption, the maximum likelihood (ML) estimator can be used to estimate the threshold parameters. However, this often requires large sample sizes. Instead, variants of weighted least squares (WLS) estimators can be used, and the mean and variance-adjusted WLS (WLSMV) is recommended (Wang and Wang 2012). After the threshold parameters are estimated, the results can be used to estimate the polychoric correlation (correlation between two latent categorical indicators). Then the estimated polychoric correlation is used to estimate the parameters in the factor model (Millsap and Yun-Tein 2004).

Let  $f_k(\mathbf{x}|\boldsymbol{\mu}_k^*, \boldsymbol{\Sigma}_k^*)$  be the distribution of observed indicators conditional on the membership to class  $k$  and class-

specific parameters  $\boldsymbol{\mu}_k^*, \boldsymbol{\Sigma}_k^*$ . Then the joint probability of observing the indicator  $\mathbf{x}$  is the mixture of the unconditional membership probabilities,  $\pi_k$ , and class-specific densities,  $f_k(\mathbf{x}|\boldsymbol{\mu}_k^*, \boldsymbol{\Sigma}_k^*)$ :

$$f(\mathbf{x}|\boldsymbol{\mu}^*, \boldsymbol{\Sigma}^*) = \sum_{k=1}^C \pi_k f_k(\mathbf{x}|\boldsymbol{\mu}_k^*, \boldsymbol{\Sigma}_k^*). \quad (6)$$

Then the probability that individual  $i$  belongs to class  $k$  can be obtained using Bayes' rule:

$$\pi_{ik} = \frac{\pi_k f_k(\mathbf{x}_i|\boldsymbol{\mu}_k^*, \boldsymbol{\Sigma}_k^*)}{\sum_{i=1}^C \pi_k f_k(\mathbf{x}_i|\boldsymbol{\mu}_k^*, \boldsymbol{\Sigma}_k^*)}. \quad (7)$$

After the LCA model is estimated, the consumption frequency regression is estimated conditional on the class. These two parts can be integrated and estimated in one step, which may produce more efficient estimators. However, such an approach may exhibit conceptual flaws, as the auxiliary regression can affect latent class formation (Vermunt 2010). In this study, latent class formation reflects the general food lifestyle, whereas the regression depicts a very specific



behavior (salmon consumption). Thus, the auxiliary regression influencing class formation is not desirable. In such instances, researchers typically employ posterior analysis in which consumers are assigned to their most likely class; i.e., an individual is assumed to deterministically belong to the class in which the estimated individual class membership probability is the highest. However, doing so will ignore the probabilistic nature of class membership. In order to account for this feature of the LCA, we follow the method proposed by Asparouhov and Muthén (2013), in which the membership uncertainty from the LCA can be incorporated into the auxiliary regression estimation.

In the Asparouhov and Muthén (2013) approach, a standard LCA is first estimated. From this, one can obtain the estimated class membership probability  $\pi_{ik}$  (the probability that individual  $i$  belongs to class  $k$ ). The most likely class

variable,  $S$ , takes  $j$  if  $\pi_{ij} > \pi_{ik} \forall k = 1, \dots, C, k \neq j$ ). Then as the second step, classification uncertainty between the class 1 and class 2, for example, is computed as follows:

$$P_{C_{1,2}} = (C = 2 | S = 1) = \frac{1}{N_{C_1}} \sum_{S_i=C_1} P(C_i = C_2 | \mathbf{x}_i) \quad (8)$$

where  $N_{C_1}$  is the number of observations with  $S = 1$ ,  $S_i$  is the most likely class for individual  $i$ , and  $C_i$  is the true latent class for the  $i^{\text{th}}$  individual. The classification uncertainties for other sets of classes are computed in a similar fashion. Then the probability that an individual is wrongly assigned to a class can be calculated as:

$$q_{C_{1,2}} = (S = 1 | C = 2) = \frac{P_{C_{1,2}} N_{C_1}}{\sum_{j=1}^C P_{C_{j,2}} N_j}, \quad (9)$$

where  $q_{C_{1,2}}$  represents the measurement error associated with classifying an individual to class 1, while the correct classification would have been class 2. Note that if the classes are perfectly and deterministically separated (e.g.,  $\pi_{i1} =$

1 and  $\pi_{i2} = \pi_{i3} = 0$ ), the uncertainty adjustment is zero. The same measure can be computed for all the pairs of  $S$  and  $C$ .

In the third step, the auxiliary regression is estimated jointly with the LCA analysis, while the uncertainty rate is held at the pre-fixed level computed in the previous step. The auxiliary regression is a simple regression of consumption frequencies on product perceptions and a set of socioeconomic controls conditional on the latent class:

$$\begin{aligned} ConsFreq|k = & \alpha^k + \beta_1^k Healthiness + \beta_2^k Value + \\ & \beta_3^k Convenience + \gamma^{k'} Z + \varepsilon \end{aligned} \quad (10)$$

where  $Z$  is a matrix of socioeconomic controls.

#### 4.5. Estimation

The estimation was conducted using the software MPlus Version 7 (Muthén and Muthén 1998-2012).<sup>3</sup> As discussed in the methodology section, it is necessary to impose parameter restrictions to achieve identification. Here, mean values for the latent responses for one class (a base group) is set to zero. Furthermore, threshold parameters are set to be equal among classes ( $\tau_{rjm}^k = \tau_{rjm} \forall k = 1, \dots, C$ ). The factor means,  $\boldsymbol{\kappa}_k$ , is fixed at zero for one class (base), the factor covariance matrix is fixed as  $\boldsymbol{\Theta}_k = \mathbf{I}$  for one class, and one element of  $\lambda_{jk}$  is fixed at 1 for each latent construct. All the latent intercepts,  $\boldsymbol{\nu}$ , are fixed at zero. Also, the measurement model is invariant across classes;  $\boldsymbol{\Lambda}_k = \boldsymbol{\Lambda}$ . These constraints reduce the number of estimated parameters to assure identification. In the factor model, the number of data points is computed as  $q(q + 1)/2$ , where  $q$  is the number of measurement indicators for latent endogenous variables. This represents the number of distinct

elements in the observed covariance matrix; thus, the maximum of  $(q + 1)/2$  parameters can be identified. Our model has  $q = 21$  (7 latent exogenous variables  $\times$  3 indicator variables), leading to 231 unique data points. To illustrate, an LCA estimation with  $C=3$  with the above specification and restrictions has 156 parameters to be estimated. Thus, the model can be identified under these restrictions.<sup>4</sup>

As a first step of the estimation, the initial LCA is conducted. To ensure the global maxima, 1,000 sets of randomly selected starting values are used in the first step of the optimization. Then 200 best starting values in terms of the log-likelihood values are used in the subsequent stages of the optimization. Since the number of classes is not an endogenously estimated parameter within the model, it is necessary to estimate models with different numbers of segments and compare the model fit based on several criteria.

The usual fit statistics, such as root mean squared error of approximation (RMSEA), comparative fit index (CFI), and Tucker-Lewis index (TLI) in SEM are not available for mixture models, but other fit statistics, namely Akaike information criteria (AIC), Bayesian information criteria (BIC), and sample-size-adjusted BIC, as well as entropy, can be used to compare solutions (Wang and Wang 2012). The fit statistics for one- to four-class solutions for each country are presented in table 4 (Appendix). Smaller values for the information criteria indicate better fit. Entropy is a measure of classification quality and takes a value between 0 (no fit) to 1 (perfect fit). There is no formal test for the entropy<sup>5</sup>, but the literature suggests values greater than 0.8 as an indication of a good fit (Wang and Wang, 2012).

Another criterion for judging the quality of the solution is reliability (Geiser 2012). One can evaluate two sets of estimates on class size; one based on the most likely class (an individual is assigned to a class with the highest estimated class membership probability) and another based on the posterior probabilities in equation (7). When these two are close, it is an indication of a good precision, as it means that an individual is more likely to be assigned to his/her most likely class. This can be checked using the matrix of average latent class probabilities for most likely latent class membership by latent class, a standard output from MPlus. The literature suggests that the diagonal values from this matrix should at least be 0.8 for a good class solution (Geiser 2012). All the solutions have diagonal values exceeding 0.9 (not shown here), so reliability is good.

Based on the number of criteria discussed above, we select a three-class solution for Russia, which has the lowest values for the information criteria. For United Kingdom, France, and Sweden, an investigation of segment size reveals that one of the segments is quite small, with only a fraction of the consumers belonging to it. Having such a small segment is not particularly informative in this context (for example, the smallest segment from the UK consists of only about 30 individuals from the sample); thus, we select a three-segment-solution as our best. For Germany, a four-class solution results in the best information criteria with reasonable class sizes. Thus, we select the 4-class solution for Germany.<sup>6</sup>

Given the number of classes, the next step is to identify the most likely class for each individual, as well as the uncertainty associated with this assignment. We computed these



adjustment factors following Asparouhov and Muthén (2013). After the LCA estimation and implementation of uncertainly adjustments, we conducted the regression analysis specified in equation (10). Class-specific models are estimated as is the pooled model for comparison.

*Latent Food Lifestyle Segments*

The LCA produces the latent class based on the seven latent food lifestyle dimensions: *freshness, health, taste, cooking method, convenience, importance of product information, and price/quality relations*. As our focus in the LCA model is the class assignment itself, rather than parameter values in the measurement model, we provide only mean factor scores for each of the seven food lifestyle dimensions (the segmentation bases) in table 5 (appendix) to highlight the differences. The three (four for Germany) segments constructed by LCA are

denoted as *High*, *Mid*, (additional group of *Mid2* for Germany) and *Low* groups, as these segments are characterized by the high, medium, and low mean scores of the food lifestyle dimensions. The *High* segment has high scores on all the food lifestyle dimensions. The only exception is *convenience*, such that the *High* segment has the lowest score, and the *Low* segment has the highest. Thus, the *High* segment can be interpreted as a group with high involvement with food—they have high interests in food in general, spending time to understand product information, like to cook, and take time to consider health and nutritional aspects of food. Thus, it makes sense that this group has a low score for convenience,<sup>7</sup> as consumers in this group do not mind thinking about and dealing with food. On the contrary, the *Low* groups consist of consumers who, in general, do not care much about food. They do not like to cook and appreciate convenience. The *Mid*

groups are inbetween the *High* and *Low* groups in terms of mean scores, indicating that *Mid* groups are more moderate in terms of their relationship with food. For Germany, the *Mid2* group is located in between *Mid* and *Low* group in terms of the factor mean.

Segments size is also important, as it can provide insights on the corresponding market size. The size of each segment is reported in table 5. Roughly speaking, the *High*, *Mid*, and *Low* groups consists of about a quarter, a half, and a quarter of the consumer population. For Germany, the two middle groups are the largest and take about a third of the market each, while *High* and *Low* groups are smaller and similar in size.

### *Average Consumption Frequencies by Segment*

First, we present the raw comparisons of the lifestyle segments by annual salmon consumption frequencies. Table 6 provides average consumption frequencies, statistical significance of the differences by segment in each country by ANOVA, and subsequent t-tests for pairwise comparisons.

**Table 6. Mean Annual Salmon Consumption Frequencies by Lifestyle Segment**

	<i>High</i>	<i>Mid</i>	<i>Mid2</i>	<i>Low</i>	F-stat	p-value
UK	21.79 <sup>ab</sup>	15.85 <sup>ac</sup>		9.55 <sup>bc</sup>	15.572	0.000
Germany	19.48 <sup>ab</sup>	15.8	11.7 <sup>a</sup>	11 <sup>b</sup>	5.690	0.001
France	17.09	17.71		14.32	1.747	0.175
Russia	17.32 <sup>a</sup>	11.6 <sup>a</sup>		14.69	6.788	0.001
Sweden	26.27 <sup>a</sup>	22.82 <sup>b</sup>		13.43 <sup>ab</sup>	16.412	0.000

Note: Superscripts a,b, and c indicate that the mean values are statistically significantly different at  $\alpha = 0.05$  by pairwise comparisons. F-stat is based on the null hypothesis that means are invariant across classes in each country, and the corresponding p-values are also presented.

In general, salmon consumption frequencies align well with the *High*, *Mid*, and *Low* levels of food-lifestyle segments such

that *High* consumers tend to consume salmon more frequently, while *Low* consumers tend to consume salmon less frequently. The differences are jointly significant (see p-values in table 6), indicating that the life-style segmentation captures the differences in average salmon consumption patterns in all target countries. The notable exception is France, where consumption frequencies do not follow the same pattern, and the mean differences are not jointly significant (p-value = 0.175).

Based on lifestyle segmentation, salmon consumption frequency is highest among Swedish *High* consumers, with an average of 26 consumption occasions per year. This corresponds to roughly once in two weeks, which shows that even among the highest consuming group, consumption frequency does not reach once a week on average. The lowest

consumption group is the *Low* group in the UK, with an average of 10 consumptions per year, or less than once a month.

#### **4.6. Consumption Frequency Regression: Results and Discussion**

The parameter estimates from the consumption frequency regression conditional on the latent class is shown in table 7, as well as the results when the data is pooled (i.e., consumer heterogeneity characterized by the latent segment is ignored). The perceptual variables are labeled as *Health\_P* (perceived healthiness), *Value\_P* (perceived value for money), and *Conv\_P* (perceived convenience). In all the estimations, basic socioeconomic characteristics are controlled for. Consistent with the findings from the literature, better perceptions seem to be associated with higher consumption frequencies by

looking at many significant perception variables in the pooled model, with some variations among countries. However, one can see the different patterns across food lifestyle segments and countries, showing that our approach provided new insights.

**Table 7. Consumption Frequency Regression Estimation Results**

	Variable	<i>Pooled</i>	<i>High</i>	<i>Mid</i>	<i>Mid2</i>	<i>Low</i>
UK	Health_P	0.526 (0.627)	0.162 (0.894)	-0.939 (0.731)		4.281*** (1.165)
	Value_P	1.776*** (0.6)	2.271** (0.956)	1.298 (0.916)		-0.066 (1.577)
	Conv_P	2.533*** (0.676)	2.101** (0.883)	3.261*** (0.96)		1.953 (1.635)
Germany	Health_P	0.039 (0.054)	2.660 (1.618)	-1.854 (1.656)	0.847 (0.704)	0.606 (1.024)
	Value_P	0.231*** (0.057)	0.696 (1.898)	3.648*** (1.039)	1.344* (0.796)	1.625* (0.934)
	Conv_P	0.138** (0.054)	3.911*** (1.517)	0.471 (1.088)	1.241* (0.732)	0.111 (0.896)
France	Health_P	0.106** (0.051)	1.295 (1.118)	-0.85 (0.973)		1.929*** (0.675)
	Value_P	0.134*** (0.048)	1.622 (1.181)	1.778* (1.004)		1.59* (0.814)
	Conv_P	0.133** (0.052)	0.133 (1.209)	1.951* (1.162)		2.363*** (0.744)
Russia	Health_P	-0.287 (0.468)	-0.052 (1.213)	0.907* (0.481)		-1.375 (0.957)
	Value_P	1.658*** (0.461)	1.643 (1.202)	1.643*** (0.534)		1.571*** (0.798)
	Conv_P	0.113 (0.5)	0.561 (1.318)	-0.026 (0.926)		0.315 (0.503)
Sweden	Health_P	-0.316 (0.612)	-1.363 (0.992)	2.47* (1.39)		-0.552 (0.751)
	Value_P	1.104* (0.604)	1.759* (0.973)	-0.235 (1.606)		1.184 (0.964)
	Conv_P	2.921*** (0.656)	3.736*** (1.134)	1.276 (1.882)		1.838** (0.883)

Note: All estimations contain the basic socioeconomic controls (age, education, gender, and marital status). The full results are available from authors. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ . Standard errors are in parentheses.



In the UK, perceived healthiness of salmon is not associated with higher consumption frequency. This is somewhat surprising as health is usually one of the important factors that consumers tend to mention for eating salmon. However, our results show that improved perceived healthiness does not increase the consumption frequency when all the respondents are pooled. When looking at the latent segments, however, perceived healthiness has a positive and significant effect in the *Low* group, indicating that improving the perception of healthiness of salmon increases consumption frequency among consumers in the *Low* group. This may be because *Low* group consumers with low food involvement have more variation in terms of knowledge about health and salmon, as low food involvement implies a general lack of interest in food. Thus, among the *Low* group consumers, those who do think that salmon is healthy seem to eat salmon more

frequently. The size of the effect is quite large, such that a 1 point increase in the perception rating results in the increase in annual consumption frequency by 4.3, on average. This may indicate that targeted communication towards this group could yield both public health and commercial benefits. Similarly, improved perception of value for money positively affects consumption frequency only among *High* consumers, and improved perception of convenience increases the consumption frequency among *High* and *Mid* consumers. It is interesting that higher perceived convenience is associated with *High* and *Mid* consumers, who are less concerned about convenience in general food lifestyle measures. It may indicate that, even among the *High* and *Mid* groups who supposedly have higher food involvement, perceived inconvenience of salmon is still a barrier for a higher consumption; a 1 point decrease on the convenience rating

reduces the consumption frequency by 2 to 3 a year, on average.

The source of the perception about (in-) convenience in relation to salmon is not illuminated in our study. The UK and France are known as the two European salmon markets with the most advanced offering of convenient fresh product forms, like portions of boneless salmon packed in a modified atmosphere (MAP) for freshness. The fact that the UK is an advanced market with a variety of convenient products already offered, could imply that a source of perceived inconvenience is found in the consumers' own knowledge about salmon cooking rather than in the product itself.

Germany is the only market where four-segments are found. Germany is known by the salmon industry as a price sensitive,

discount retail market dominated with smoked and frozen products, distinct from other large markets such as the UK and France. Thus, finding a different consumer segments pattern may not be so surprising. It is also somewhat expected that perceived value and convenience are found to have positive and significant effects overall. Improved perceived value seems to affect *Mid*, *Mid2*, and *Low* consumers, while improved perceived convenience significantly increases consumption frequency among *High* consumers. Thus, the perception that salmon provides good value for the money seems to be an important aspect for consumers in *Mid*, *Mid2*, and *Low* segments, while it does not have any significant effect on *High* consumers. On the other hand, improved perceived convenience has a strong and positive effect among *High* consumers; a 1-point increase in this perception is

estimated to increase the annual consumption frequency by 3.9.

For French consumers, although all three perception variables are significant overall, inspection across food lifestyle segments reveals that the action mainly comes from the *Low* consumers. In particular, improving all three perceptions seems to increase salmon consumption frequencies; a 1 point increase in health perception and convenience perception increases annual consumption by 1.9 and 2.4, on average. Improved perceived value and convenience have marginal positive effects on consumption frequency among *Mid* consumers, but none of the perceptual variables were significant for *High* consumers. This may be because the French market is relatively mature so there is not much variation among *High* and *Mid* consumers in terms of their

salmon perceptions. Provided that they are already eating salmon rather frequently, it may also mean that it is more difficult to increase consumption frequency through changed perceptions alone.

In Russia, only the perceived value is significant overall, and this comes from both *Mid* and *Low* consumers. Thus, improving on value perception may increase salmon consumption among *Mid* and *Low* segment consumers. The average increase in annual consumption frequency is about 1.6 for both perceptions. Like French consumers, *High* Russian consumers are also unaffected by the improved perceptions about salmon. Russia is a large, growing market for farmed salmon with a limited variation in product forms compared to more mature markets like the UK and France. Studies of Russian seafood consumers have revealed that healthy eating

is not a primary concern in food choice (e.g., Honkanen and Frewer 2009), and criteria like sensory factors, availability, and price prevail. Pronounced effects from perceived value for money should therefore be expected in Russia, as salmon is increasingly made available through the growth of modern grocery distribution (MGD) retailer formats. MGD allows for more choices in salmon products in convenient and fresh MAP-forms that enhance both availability and the sensory aspects of the products. This implies that one can expect an increased demand from Russian consumers as the domestic retail formats and products evolve.

Finally, in Sweden, perceived convenience seems to be the key factor; improved perceived convenience positively affects salmon consumption frequency. A 1-point increase in perceived convenience increases annual consumption

frequency by 3.7 for *High* and 1.8 for *Low* consumers. Again, MGD provides Swedish consumers with convenient salmon products. The significant effect found in improved perceived convenience may indicate that such improvement in perception may not be linked to increasing offering of convenient product forms of salmon, but it may be dependent upon improved product knowledge.

#### **4.7. Conclusion**

Food consumption decisions are complex, as they are affected by various personal values and ideals, real-life constraints, as well as social and cultural dynamics. Since consumers are different in these aspects, food choices are inherently heterogeneous. For consumer researchers and marketers, accounting for underlying heterogeneity is a key to better understand consumer market behavior. This article provides insights by applying the general framework of FRL in an



investigation of the relationship between product perceptions and consumption frequencies for salmon. We find significantly different salmon consumption frequencies and varying marginal effects from specific product perceptions among food-lifestyle segments, although consumer segmentation of food-lifestyle itself is not directly based on salmon or seafood consumption behavior. This indicates that there exist general cognitive values, as suggested by the theoretical model of FRL, which influence specific behavior, such as consumption frequencies of salmon.

The effect of product perceptions on consumption frequencies is important, as various marketing activities aim to change consumers' perceptions, hoping to change their behavior to their advantage. However, different patterns emerge for

different consumer lifestyle segments, as well as for different markets.

Probably one of the most emphasized aspects of eating salmon is health. However, our analysis shows that improving the perceived healthiness of salmon only modestly affects consumer behavior. This finding challenges a common opinion in the industry that increased marketing communication about health benefits will generally strengthen demand. The notion that salmon is a healthy food is now a widespread, strong perception among consumers after decades of communicating its health benefits. This generally established knowledge among consumers may explain why health perceptions influence consumer behavior only to a modest degree.

So far, our focus has been on the implications of improvement in perceptions. However, a real issue in the salmon industry is, in fact, a potential decrease in the health perception. Due to feed supply constraints, demand growth, and sustainability issues, the salmon industry has reduced the content of omega-3 fatty acid in farmed salmon, a key component of the healthiness argument (Tveterås and Tveterås 2010; Tacon and Metian 2008). Although current levels are in line with wild salmon and are among the richest in omega-3 in the general seafood category, these changes causes some concern among producers and processors in relation to possible adverse consumer responses. The findings from the current study do not imply a significant change in consumption frequencies from a change in perceptions about healthiness. However, for any such conclusion in relation to salmon products to be validated, further studies are required.

The other two perceptions considered in this study, value for money and convenience, turned out to have stronger linkages to consumption frequencies, in a sense that higher scores on these perceptual dimensions would significantly increase consumption frequency. This may be due to the fact that there is more room for improvement on these two perceptions compared to the well-established perception of salmon as healthy food. However, it is less clear as to how one could improve perceived value and convenience regarding salmon. Varied market conditions for the considered markets may imply different things. For countries considered “advanced” in terms of the salmon market, such as the UK and France, where MGD brings fresh, convenient salmon products, it may be more a matter of consumers’ lack of knowledge and familiarity with preparing salmon, giving the perception of inconvenience. It is also possible that lack of knowledge and

familiarity gives the consumer an impression that salmon has inferior value. For example, a person may know many different ways to cook chicken compared to salmon, thus, considers salmon as lacking versatility and perceives less value for the money. For countries like Russia and Germany, there might be potential demand growth through introducing fresh, convenient products. Such changes in product format and distribution should improve perceived convenience and thus, demand. The argument of lack of knowledge and familiarity may apply to these markets, as well. Another aspect that may be important but one not addressed in this study is a habit formation (e.g., Verplanken and Wood 2006). Habit is reported as an important factor in seafood consumption (Honkanen, Olsen, and Verplanken 2005). Our study, however, provides an indication that the *Low* consumers may at least begin to build a habit of consuming more salmon if

marketers can successfully lower the perceptual barriers; e.g., perceived inconvenience.

The results from this study based on the micro-level analysis of individual's FRL can also provide useful information in order to understand and/or predict changes in market behavior at an aggregate level. To wit, take Germany and consider the aggregate impact of a one-unit improvement in the perceived convenience; e.g., via introduction of portioned MAP salmon products among *High* consumers. This group consists of about 16% of German consumers. Given a population of 82 million, and a salmon portion size of 150 grams, such change in consumption behavior implies 51.2 million extra portions consumed, or about 12,500 tons wet fish equivalent (WFE) sold in Germany.<sup>8</sup> With a 40 NOK per kilo WFE price, such a change in consumer behavior would add annual firsthand

revenue of approximately 60 million euros, a figure that would be multiplied by domestic seafood processor and retailer costs and margins. The question of return on investment cannot be answered without knowing the investment cost of moving a preference one point on the scale within the defined target group (*High*). An answer to this, however, includes product development, distribution, and market communication efforts over time. A combination of factors, like the findings in Germany and Russia, can be useful in explaining the reasons behind a particular product and market structures in a country and in predicting demand growth in these markets.

Solid, detailed knowledge about factors that influence demand for seafood among consumer segments is important for the design of marketing activities, product development schemes, and public health policy formulation. Findings from this study

can guide such decision-making; however, understanding the link between FRL and other life style preferences, such as media consumption and shopping formats, would be crucial, as such knowledge will enable more precisely targeted marketing. For example, future work on how to identify the target segments using observable characteristics that are correlated to the latent lifestyle segments could be fruitful. Any campaign budget is limited, and knowledge about FRL could guide priorities and improve return on investments for interested stakeholders.



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*Appendix: Table 1. Sample Characteristics*

	Category	UK	Russia	Germany	France	Sweden
Gender	Male	46%	53%	51%	51%	51%
	Female	54%	47%	49%	49%	49%
Civil status	Married	48%	52%	42%	36%	34%
	Single	24%	19%	29%	26%	32%
	Divorced	7%	10%	10%	11%	8.3%
	Widowed	2%	6%	2%	0.4%	2%
	Domestic partner/ cohabitants	19%	13%	17%	26%	24%
	Age	20 to 29	21%	28%	22%	26%
	30 to 49	26%	45%	48%	48%	44%
	50 to 59	39%	22%	19%	14%	15%
	60 and up	14%	6%	11%	12%	18%
	Mean age	42	39	42	49	43
Education	High school	23%	25%	54%	16%	42%
	More than high school	34%	52%	25%	39%	46%
	More than college	43%	23%	21%	45%	13%
Household size	Mean	2.86	3.32	2.40	2.74	2.36
Children in household	Mean	1.56	1.65	1.40	1.63	1.39
Median income category		£20K to £30K	360K to 720K RUB	€24K to €50K	€25K to €50K	300K to 500K SOK
N		495	501	476	476	500

**Appendix: Table 4. Fit Statistics**

Country		Segment Number			
		1	2	3	4
UK	Log-likelihood	-17,183.431	-16,086.783	-15,745.681	-15,613.919
	#Param	138	146	154	162
	AIC	34,642.861	32,465.565	31,799.362	31,551.837
	BIC	35,223.090	33,079.431	32,446.864	32,232.976
	ABIC	34,785.075	32,616.024	31,958.065	31,718.784
	Entropy	1	0.916	0.893	0.892
	Class1	1	0.58	0.46	0.07
	Class2		0.42	0.31	0.22
	Class3			0.24	0.34
	Class4				0.37
Germany	LL	-16,757.298	-15,622.401	-15,299.017	-15,134.981
	#Param	140	148	156	164
	AIC	33,794.597	31,540.802	30,910.034	30,597.961
	BIC	34,377.755	32,157.284	31,559.839	31,281.090
	ABIC	33,933.415	31,687.552	31,064.717	30,760.577
	Entropy	1	0.923	0.889	0.885
	Class1	1	0.48	0.45	0.16
	Class2		0.52	0.22	0.38
	Class3			0.33	0.13

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	Class4				0.34
France	LL	-17,847.8	-16,840.8	-16,448.18	-16,277.743
	#Param	140	148	156	164
	AIC	35,977.57	33,977.62	33,208.36	32,883.486
	BIC	36,572.11	34,601.68	33,866.15	33,575.009
	ABIC	36,124.57	34,131.92	33,370.997	33,054.462
	Entropy	1	0.889	0.895	0.908
	Class1	1	0.49287	0.26	0.23
	Class2		0.50713	0.24	0.29
	Class3			0.50	0.04
	Class4				0.44
Russia	LL	-17,026.3	-16,053.4	-14,341.802	-15,557.6
	#Param	141	148	156	164
	AIC	34,334.69	32,402.73	28,995.604	31,443.28
	BIC	34,931.46	33,029.13	29,645.409	32,137.4
	ABIC	34,483.91	32,559.36	29,150.287	31,616.84
	Entropy	1	0.901	0.843	0.888
	Class1	1	0.67039	0.21	0.45
	Class2		0.32961	0.36	0.21
	Class3			0.43	0.05
	Class4				0.29
Sweden	LL	-17,637.910	-16,532.629	-16,104.695	-15,931.927

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#Param	140	148	156	164
AIC	35,555.820	33,361.257	32,521.391	32,191.854
BIC	36,145.865	33,985.019	33,178.870	32,883.050
ABIC	35,710.497	33,515.258	32,683.716	32,362.504
Entropy	1	0.901	0.902	0.898
Class1	1	0.51	0.51	0.20
Class2		0.49	0.23	0.41
Class3			0.26	0.07
Class4				0.32

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*Appendix: Table 5. Mean Scores and CI for the Food Lifestyle Dimensions by Segments and Country*

		<i>High Segment</i>			<i>Mid Segment</i>			<i>Mid2 Segment</i>		
		Factor Mean	95% CI		Factor Mean	95% CI		Factor Mean	95% CI	
			Lower	Upper		Lower	Upper		Lower	Upper
UK	PI	4.06	3.27	4.85	1.58	1.04	2.12			
	PQ	4.79	3.80	5.78	2.13	1.44	2.83			
	FR	3.34	2.68	4.00	1.64	1.22	2.06			
	HL	4.41	3.70	5.11	1.73	1.26	2.19			
	CV	-0.62	-1.20	-0.05	-0.53	-1.12	0.06			
	CK	0.86	1.44	0.28	0.42	0.75	0.09			
	TS	3.72	2.75	4.70	1.87	1.32	2.41			
Segment Size			0.24		0.47					
Germany	PI	5.41	4.61	6.20	2.93	2.11	3.75	1.76	0.98	2.55
	PQ	8.51	6.88	10.14	4.67	3.25	6.09	2.61	1.80	3.41
	FR	4.91	4.10	5.72	3.39	2.66	4.11	1.61	1.10	2.11
	HL	6.43	5.34	7.53	4.01	3.09	4.94	2.06	1.57	2.55
	CV	-1.62	-2.47	-0.77	-1.35	-2.06	-0.63	-0.25	-0.80	0.29
	CK	1.07	0.75	1.39	0.70	0.19	1.20	0.30	-0.05	0.65
	TS	4.53	3.68	5.37	2.38	1.53	3.23	1.28	0.79	1.76
Segment Size			0.16		0.33		0.38			
France	PI	4.64	3.91	5.38	2.62	3.24	2.01			
	PQ	3.35	2.83	3.87	1.45	2.21	0.69			

	FR	3.61	3.11	4.12	1.70	2.17	1.22
	HL	5.02	4.36	5.67	2.53	3.01	2.05
	CV	-0.11	-1.03	0.81	0.37	0.75	-0.01
	CK	0.85	1.47	0.23	0.37	0.11	0.62
	TS	3.77	3.24	4.29	1.61	2.34	0.89
	Segment Size		0.26			0.50	
Russia	PI	4.35	3.56	5.13	1.62	2.28	0.96
	PQ	5.35	4.39	6.32	2.71	3.44	1.97
	FR	2.97	2.49	3.45	1.51	1.91	1.10
	HL	4.54	3.82	5.27	1.70	2.37	1.03
	CV	0.02	0.01	0.03	0.01	0.02	0.00
	CK	0.32	-0.13	0.78	-0.11	-0.05	0.28
	TS	1.89	1.52	2.26	1.00	1.65	0.34
	Segment Size		0.21			0.43	
Sweden	PI	4.68	3.79	5.57	2.01	1.41	2.60
	PQ	4.92	4.01	5.82	2.22	1.61	2.83
	FR	3.66	2.97	4.36	1.98	1.57	2.38
	HL	5.69	4.85	6.52	2.65	2.18	3.12
	CV	-1.45	-2.04	-0.86	-0.82	-1.40	-0.23
	CK	1.40	2.00	0.81	0.82	1.17	0.46
	TS	3.85	3.01	4.70	1.88	1.35	2.41
	Segment Size		0.23			0.52	



Note: **Reference segment** (*Low*) has the factor mean equal to zero. Abbreviations are PI=Importance of product information, PQ=Price quality ratio, FR=Freshness, HL=Health, CV=Convenience, CK=Cooking method, TS=Taste.

### ***Appendix: Food Related Lifestyle Dimension Indicator Questions***

Abbreviation indicates the corresponding FRL dimensions;

PI=Importance of product information, TS=Taste, PQ=Price/quality relations, CV=Convenience, CK=Cooking methods, FR=Freshness and HL=Health. Each dimension is measured by three statements.

Responses are from 1=strongly disagree to 7=strongly agree. The statements with reversed scales are shown with (R) after each statement. The number in the brackets at the end of each statement represents the order of the questions asked in the survey, which follows the same order as in the original FRL questionnaire.

- PI1. To me product information is of high importance. I need to know what the product contains. (1)
- PI2. I compare labels to select the most nutritious food. (10)
- PI3. I compare product information labels to decide which brand to buy. (4)
- PQ1. It is important for me to know that I get quality for all my money. (3)
- PQ2. I always try to get the best quality for the best price. (21)
- PQ3. I compare prices between product variants in order to get the best value for money. (5)
- FR1. I prefer fresh products to canned or frozen products. (9)
- FR2. It is important to me that food products are fresh. (12)
- FR3. I prefer to buy meat and vegetables fresh rather than pre-packed. (14)
- HL1. I try to avoid food products with additives. (15)
- HL2. I prefer to buy natural products, i.e. products without preservatives. (18)
- HL3. To me the naturalness of the food that I buy is an important quality. (11)
- CV1. We use a lot of ready-to-eat foods in our household. (6)
- CV2. Frozen foods account for a large part of the food products I use in our household. (17)
- CV3. I use a lot of mixes, for instance baking mixes and powder soups. (19)
- CK1. I don't like spending too much time on cooking (R). (7)

- CK2. I like to have ample time in the kitchen. (13)
- CK3. Cooking is a task that is best over and done with (R). (20)
- TS1. I find taste in food products important. (2)
- TS2. When cooking I first and foremost consider taste. (8)
- TS3. It is more important to choose food products for their nutritional value rather than for their taste (R). (16)

## ENDNOTES

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<sup>1</sup> The LCA is also known as the semiparametric heterogeneity model (Heckman and Singer 1984) and finite mixture model (Jedidi, Jagpal, and DeSarbo 1997).

<sup>2</sup> Since the use of a lifestyle measure was only part of the larger research project, it was not feasible to include all 69 questions in the survey.

<sup>3</sup> A detailed procedure for implementing the three-step approach using MPlus is described in Asparouhov and Muthén (2013).

<sup>4</sup> These are the necessary but not sufficient conditions for the identification. The identification in SEM is quite complex, but computer software can be used to check for further identification problems (Wang and Wang 2012).

<sup>5</sup> In MPlus, entropy is computed as  $E_C = 1 - \frac{-\sum_i \sum_k \pi_{ik} \ln \pi_{ik}}{N \cdot \ln(C)}$ .

<sup>6</sup> A five-class solution for Germany had slightly smaller values for the information criteria, but one of the classes only contained 1% of the respondents.

<sup>7</sup> Here, convenience is fairly narrowly defined by the FRL framework; e.g., use of frozen food and ready mixes.

<sup>8</sup> The weight of a boneless and skinless portion of salmon is approximately 60% of the whole fish.