UiT
THE ARCTIC UNIVERSITY OF NORWAY

Faculty of Biosciences, Fisheries and Economics, School of Business and Economics

Why do Prices Change?

An Analysis of Supply and Demand Shifts and Price Impacts in the Farmed Salmon Market

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Eivind Hestvik Brækkan

A dissertation for the degree of Philosophiae Doctor – July 2014

Summary

Price changes in any market are essentially due to shifts in supply relative to demand. In a global market there can be several simultaneous supply and demand shifts in different geographical locations, all affecting prices to different extents. This dissertation focuses on procedures for measuring such shifts and their relative effects on prices by looking at the global market for farmed salmon in the period between 2002 and 2011. Farmed salmon is a relatively homogeneous, globally traded product whose market size has burgeoned over the last 30 years.

The first paper determines the magnitude of the shifts in annual demand across all salmon-importing regions. Results indicate that demand varies considerably between years and regions and does not appear to follow a smooth trend - as usually assumed in empirical demand analysis.

The second paper uses the same approach to determine the size of annual regional supply and demand shifts from exporting and importing regions. The impacts of these shifts on prices are determined through an Equilibrium Displacement Model. This allows the decomposition of annual price movements into the effects of regional supply and demand shifts. We find large variation in supply and demand shifts and price impacts between regions and within regions over time. Average annual shifts and price impacts for most regions are not significantly different from zero, but we detect cumulative price effects from successive shifts in demand or supply for all but one region. This suggests that even if the annual averages of regional shifts in supply or demand are zero, year-on-year shifts from most regions are significantly influencing prices.

The third paper extends the procedure of the first. We disentangle the impacts from income growth and price changes in substitute products from the total demand shift. The remaining, residual shift in demand is due to other, unknown or omitted factors. Results indicate demand shifts due to unknown factors account for a large portion of total demand growth in all salmon-consuming regions and residual demand growth is not smooth in any region. This implies we cannot account for the growth of salmon demand in recent years solely by economic factors such as income growth and/or changes in relative prices. Additionally, using a trend variable to capture unexplained demand growth will not capture the wide variations in unexplained demand over time.

Acknowledgements

First and foremost, I would like to thank my supervisors, Professors Øystein Myrland and Henry W. Kinnucan. Øystein has always encouraged me to explore any subject that triggered my curiosity and has provided valuable knowledge and guidance on my path from starting with some simple ideas into the completion of this dissertation. Henry has taught me theory and methods of fundamental importance for my work and has been a valuable resource for theoretical discussions and feedback.

I would also like to thank my co-authors Sverre Braathen Thyholdt and Øystein Myrland (again). I have learned a lot through our collaboration.

I am very grateful to the faculty and students at the Department of Agricultural and Resource Economics, UC Davis, especially to my faculty host Julian Alston. The lectures and discussions from my year spent at UC Davis taught me more than I ever imagined I would be able to learn during my time as a PhD student.

Thanks to all my good colleagues at the Tromsø School of Business and Economics, especially the administrative staff for all the practical help that makes the daily life of a PhD student so much easier.

The research project which this dissertation is based on was funded by the Research Council of Norway, with project number: 199321/I10. Acknowledgements go out to the Research Council for funding this research.

I would like to thank Paul Aandahl, Kristin Lien and the staff at the Norwegian Seafood Council as well as the staff at Capia for providing and helping to interpret invaluable data.

Final acknowledgements go out to my favourite individuals: Inger Marie, Luka Johannes and Ada Marie for providing me with endless joy and love.

Contents

List of papers

Paper 1

Brækkan, Eivind Hestvik & Thyholdt, Sverre Braathen. (Forthcoming). The Bumpy Road of Demand Growth – An Application to Atlantic Salmon. *Marine Resource Economics*

Paper 2

Brækkan, Eivind Hestvik. (Forthcoming). Disentangling supply and demand shifts: the impacts on world salmon prices. *Applied Economics*

Paper 3

Brækkan, Eivind Hestvik,. Thyholdt, Sverre Braathen & Myrland, Øystein (2014). The Demands They Are a-Changin'

1. Introduction

"Stripped of detail, commodity prices do indeed reflect shifts in supply relative to demand" (Tomek, 2000)

Why do prices change? In recent years we have seen dramatic price increases in a number of food commodities. These changes indicate large shifts in supply relative to demand. It can be difficult to determine the size and impact on price from each specific shift. If demand is growing at the same time as supply is contracting, both events cause the price to increase. What then is the relative impact on price from each factor? The empirical focus of this dissertation is on the global market for farmed salmon. Improved technology has caused prices to drop substantially as production increased from the early beginning in late 1970s up until the early 2000s. Since the early 2000s prices have slightly increased, with continuing quantity growth. This suggests that demand growth is outpacing supply growth. Throughout this period, there have been disease problems in several salmon-producing regions; steep income growth in several salmon-consuming regions; a global financial crisis; and high volatility in the price of salmon, input factors, and substitute products. These events make the global salmon market an excellent example for determining the causes behind price behaviour. The papers in this dissertation focus on regional supply and demand shifts in the global salmon market and their impacts on price. To facilitate the understanding of the driving forces behind shifts in supply and demand this dissertation begins with a review of these concepts.

2. What is the true nature of supply and demand?

Demand and supply are fundamental concepts for any economist. Shifts in demand and supply drive the development of prices and quantities sold in any market. Marshall (1920) establishes the principle of the *general law of demand*, stating that the quantity demanded increases with a fall in the price. This is a fundamental assumption in demand analysis.

Supply is the quantity that producers and firms are willing to sell for every market price of a good. The fundamental principle for supply is that a fall in the price causes a reduction in quantity supplied. Smith (1863) states that a fall in the price of a product will cause suppliers to reduce quantity until the price of this product reaches it *natural* price.

Marshall (1920) illustrates this point by alluding to the truism that it takes two blades on a pair of scissors to cut a piece of paper. In the same way, both supply and demand mutually determine prices in what he refers to as the *market equilibrium* of supply and demand.

Approximating (estimating) the true nature of demand and supply curves has long caused controversy among economists. Working (1927) reviews early statistical studies of demand. His observations remain relevant as he emphasizes that the specification of an appropriate demand schedule with constantly shifting curves of demand and supply represents a major challenge. The notorious "pitfalls debate" between Frisch and Leontief (Frisch, 1933, 1934; Leontief, 1929, 1934a, 1934b) is a discussion of the assumptions that must be made with respect to the properties of demand and supply curves. Due to the economic properties of supply and demand, Leontief argues that shifts in supply and demand curves must be independent of each other. Given this restriction, Leontief derives a procedure for estimating supply and demand curves by using only price and quantity data. Frisch violently disagrees, stating that the nature of the specific data would contradict the underlying assumption of independence between shifts in supply and demand. Their disagreement reflects two fundamental approaches to demand and supply analysis; in one the economic theory of supply and demand comprises the essential foundation for useful data analysis; in the other, the data at hand be taken into consideration in any analytical approach.

Notwithstanding their disagreements, neither economist neglected the importance of both theory and data in estimating demand and supply. Leontief was a strong proponent of the use of quantitative data in the study of economics (Leontief, 1971), and Frisch is considered the founder of econometrics. Frisch's research provided a ground-breaking contribution towards bridging the gap between economic theory and data analysis (Chipman, 1998). The employment of theory and data analysis is fundamental to driving knowledge in the field of economics. Stigler (1966) argues along similar lines, stating that any economic theory with no predictive power is merely tautology. In the same way one could argue that, demand and supply analysis with no regard for economic theory gives little information about supply or demand.

2.1. Demand

On the demand side it would appear reasonable to believe that the relative stability of tastes (or preferences) compared to productivity levels would enable easier analysis than for supply. Although the constancy of tastes has been the subject of intriguing debate (Pollak, 1970; Stigler & Becker, 1977), the assumption of relatively stable tastes is still fundamental to most demand analyses.

Standard demand theory assumes that given a limited budget, a consumer will always choose a utility-maximizing bundle of goods. We assume there is a unique bundle of goods that maximizes a consumer's utility at every price and budgetary level. We refer to this as the *Marshallian demand function*. Some crucial assumptions about the consumer are usually present (and sometimes ignored) in empirical demand analysis. We assume a consumer faces a linear budget constraint and has preferences that are rational, non-satiated, continuous and strictly convex. Additionally, the consumer has perfect information, prices are linear in quantity and exogenously given to the consumer. For mathematical purposes, goods are treated as divisible. These assumptions allow the derivation of economically meaningful results. Assuming a linear budget constraint that is satisfied with equality implies homogeneity of degree zero in prices and expenditure, more commonly referred to as the absence of money illusion. Unsatisfied preferences ensure that the consumer spends the entire budget (or income). This implies that a change in the price of one good does not affect total expenditure but conversely a change in income will lead to an identical change in total expenditure.

The large number of goods available to the consumer makes empirical estimates of consumer demand difficult. Limited data and myriad parameters have engendered further assumptions that make it possible to estimate consumer demand empirically. *Separability* assumes that closely related commodities are separable from other goods. This implies a consumer pursues a two-stage budgeting process. A consumer will first choose to allocate a portion of his or her total income on a number of closely related goods before deciding how much of the allocated amount to spend on each of the individual goods. This allows estimation of demand functions based solely on expenditure and prices within the group of goods in question.

There are several models of food demand, and the choice of functional form for demand analysis is limitless. The most easily estimated are linear, logarithmic and double log single-equation models. While easy to estimate and interpret, some properties of utility maximization cannot be satisfied by the use of such models. For instance, for the double-log model, the non-satiation assumption is only satisfied if the expenditure elasticities are equal to one.

Alternatively, demand can be specified as a system of demand equations derived explicitly from consumer theory. Such demand systems are frequently applied in empirical demand analyses. The parameters estimated when using such models can be restricted to make the system satisfy the properties of the utility-maximizing consumer. Typically, there is a trade-off between the flexibility of the demand system and parsimony with respect to the number of parameters to be estimated.

The family of demand systems is quite large and increasing (see for instance Barnett & Seck (2008), and references therein). Perhaps the most common approaches to estimating demand systems are the Almost Ideal Demand System (AIDS) (Deaton & Muellbauer, 1980b) and the Rotterdam Model (Barten, 1964; Theil, 1965). As in most demand analysis, empirical results often conflict with theoretical assumptions about the rational consumer.

While procedures become more sophisticated as computer power increases and new knowledge emerges, the world is becoming more complex as well. Tomek (1985, 2000) argues that the growing complexity of food markets has made commodity demand analysis increasingly difficult. Stigler (1939) argued that the gap between theoretical demand theory and statistical demand curves will never become completely bridged. Even today, 75 years later, I expect few researchers would disagree with him.

While it has been argued that demand analysis is much less complex than supply analysis, the assumptions the demand analyses usually rely upon certainly place a deep faith in the consumer's rational capability. Add to this some assumptions made for the convenience of the researcher's analysis - such as separability and a specific functional form of the utility (or cost) function - and the consumer's leeway for utility maximization becomes rather restricted.

2.1.1. Demand shifters

Changes in income and in the prices of substitute or complementary products are the main economic reasons for demand shifts. A demand shift due to non-economic reasons is referred to as a *structural change* in demand. There is a rich literature on methods for detecting structural change in demand (e.g. Moschini & Meilke (1989) and references therein), and an infinite number of factors that may influence demand for any product.

Demand can be affected by changes in demographics such as older, more educated consumers (Tomek, 1985); changes in socioeconomic factors such as income distribution (Brown & Deaton, 1972); the appearance of new information on a product (Tomek, 1985); changes in product attributes such as product forms and quality (Ladd & Suvannunt, 1976); or, as Stigler & Becker (1977) point out, the accumulation of consumption capital.

Stone (1945) suggests using time trends to allow for systematic variation in demand caused by factors such as those mentioned above. Barten (1967; 1969) follows this approach and introduces a constant term in the Rotterdam demand system to allow for gradual changes in preferences. Deaton & Muellbauer (1980) suggest influences other than prices and total expenditures must be systematically modelled to be able to explain patterns of demand in a theoretically coherent way. They suggest using time-trend variables to explain rejections of homogeneity, since these could be an indication of changes in consumer preferences. The presence of such time trends, they argue, is indicative of other influences on consumer demand than current prices and expenditures. Such influences might include storage effects, price expectations and other omitted variables. Findings of such time trends might also indicate the assumption of separability should be rejected. Pollak & Wales (1995) provide a thorough review of various methods for taking dynamics (e.g. habit formation) and demographics into consideration in demand systems. Kinnucan et al. (1997) looks at the impact of health information and generic advertising on U.S. meat consumption using trend indicators. Piggott & Marsh (2004) investigate food safety concerns by constructing a time series index based on the prevalence of newspaper articles with adverse food safety information about beef, poultry and pork products. While the use of such indices can uncover valuable information about demand changes, they tend to move relatively smoothly over time.

The view of a household as both a producer and a consumer of goods is one aspect of demand not well integrated into empirical demand studies(Huffman, 2011). In household production theory, a household purchases market goods to produce commodities for its own consumption. This implies consumer demand for market goods is in essence a derived demand for an input factor of production, similar to a firm's demand for input factors. Stigler & Becker (1977) suggest that even with stable individual preferences, changes in factors such as human capital (due to the accumulation of knowledge and skill); shadow prices of household resources (e.g. time); and the household technology used to transform market goods into fundamental goods can cause changes in demand for market goods. In light of household production theory, one might expect a household's demand for input factors to be similarly variable as a firm's demand for input factors.

Incorporating household production theory in demand analysis is a formidable task - and beyond the scope of this dissertation. However, ignoring it may cause serious problems. Empirical demand analyses of food commodities usually ignore the opportunity cost of time spent purchasing inputs, as well as the resources required (time, equipment and human capital) for preparation and consumption of the final product. Ignoring the opportunity cost of time has been found to lead to significant specification bias (Prochaska & Schrimper, 1973).

Adding a trend variable to account for shifts in demand can lead to appropriate results if such shifts vary systematically. However, if the combined effect of omitted variables influence demand irregularly over time, a time trend will not capture this and the results will be impaired. Considering the vast array of factors potentially influencing demand, even if preferences are stable there is no *a priori* reason to expect demand for market goods to shift smoothly over time.

The market for red meat in the U.S. is one such market where demand may not have shifted smoothly. A large decline in consumption of red meat in the US has triggered significant efforts towards explaining this phenomenon, and several variations of demand systems have been applied to test for structural shifts in demand (see e.g. Chavas, 1983; Eales & Unnevehr, 1993; Moschini & Meilke, 1989; Piggott & Marsh, 2004, and references therein).

Findings that prices and expenditures are unable to explain consumption patterns over time have often led to the conclusion that 'tastes' have changed. Alston & Chalfant (1991a, 1991b, 1988) argue that findings of taste changes in demand analysis are just as likely to be caused by imposing incorrect functional forms. Using a non-parametric approach they show that changes in meat consumption patterns in the U.S. and Australia can be accounted for by changes in relative prices and expenditures. Although theoretically consistent, the choice of the wrong functional form could give results that indicate shifts in demand where such shifts did not occur, or vice versa (Alston & Chalfant, 1991b). For U.S. meat consumption there is no consensus as to whether changes in demand can be explained by changes in relative prices and expenditures or whether other factors are relevant.

Since the true functional form of consumer demand is unknown to a researcher, one can never *know* whether a structural change in demand occurs or not. Any parametric test for structural change in demand depends on a joint hypothesis of the functional form and other underlying assumptions of the specified model, and it is impossible to know whether the specified model is correct (Alston & Chalfant, 1991b). If the assumption of no shift in demand is not rejected in empirical analysis, this merely suggests that stable demand is one of a number of potential explanations. Any shift in price and/or quantities reflect the occurrence of any following events; a movement along the original demand slope due to a shift in supply; a shift in demand caused by changes in relative prices or expenditures; a shift in demand caused by other factors (a structural change in demand) or a combination of any of these factors. Since the true demand curve is unknown, the ability to explain the shift by a movement along the estimated demand curve and changes in relative prices and expenditures does not necessitate that a structural shift in demand has not occurred. If an empirical demand analysis indicates conventional demand theory (i.e. changes in income/expenditure and relative prices) is sufficient to explain changes in consumption patterns, one can never reject the possibility that there are unknown (or ignored) variables affecting demand.

The nesting of various demand systems is one approach for overcoming the issue of using incorrect functional forms. Generalized demand models that nest different demand systems permit testing various models that may provide an adequate representation of consumer preferences (see e.g. Eales, 1997). Such a nesting procedure indicate the demand system that conforms best to the data at hand. However, the problem of identifying structural shifts remains. If there are any shifts in consumer preferences and these are reflected in the data, nesting may lead to the rejection of the best model if the shift (or shifts) are not specified in the model. Even if the best model is found to be appropriate, a demand shift may not be identified if no such shift is specified in the model, or if it is specified incorrectly. While it is the usual approach adopted in the literature, it remains notoriously difficult to test for structural shifts in demand using the same data employed to estimate the parameters of the model (Chalfant & Alston, 1988).

Marsh (2003) applies an alternative approach to demand shifts. His procedure allows demand to shift independently over time. A shift in demand is defined as the difference between the observed price and the expected price; assuming the demand schedule has not changed since the previous period. Given price and quantity data and a specified elasticity parameter, a shift in demand can be computed for any period. A fundamental underlying assumption is that constant elasticity of demand is an appropriate local approximation to the unknown demand functions.

As noted above, a shift in demand can be caused by known factors such as changes in income and relative prices of substitute and complementary goods, as well as unknown factors. A demand shift as specified by Marsh encompass the shift in demand caused by all variables affecting it, both known and unknown. Hence, it can be interpreted as a gross shift in demand.

2.2. Supply

The aim of the supplier is to maximize profits. Optimal production level is assumed where marginal revenue equals marginal cost. In the presence of uncertainty, the producer must find an appropriate balance between maximizing expected profits and minimizing risk. The economist often assumes the supplier makes production decisions with respect to these two criteria. To do so the producer must decide the quantity of a good to produce given input costs and expected demand for its product. This also implies the producer must decide the optimal level and ratio of inputs. In the short run, most input factors are assumed fixed, while in the long run the producer can adjust or replace all input factors. Cassels (1933) reviews early attempts to study supply curves and identifies relevant complicating factors. He argues there can be no "*one-and-only supply curve*" for a commodity. There will be a whole series of supply curves spanning from the short-term supply curve of extreme rigidity of quantity supplied (i.e. highly inelastic), to the long-term supply curve that allows for adjustment of all factors of production, which he argues to be nearly horizontal (i.e. highly elastic). For any time span, the supply curve differs from supply curves of longer or shorter time spans. The longer the time span, the more input factors are adjustable and the more elastic the supply curve will be.

The element of time in production also involves an aspect of uncertainty for the producer. When production decisions are made, it takes a certain amount of time for a product to be finished and ready for market. Rather than the actual price of an output determining production decisions, the expected price is the determining factor. The same argument applies when the costs of all potential inputs are unknown until after production decisions have been made. The task of quantifying expectations appropriately is difficult and has a long history in the literature. See e.g. Nerlove & Bessler (2001) for a thorough review and introduction to the literature. Factors that influence the supply between periods, such as the impact of weather on agricultural yield, substitute output and input prices and productivity growth, further complicate economic analysis. Colman (1983) reviews various methods for empirically estimating supply, concluding that no single one of them was more favourable than others in every instance. He argues that the choice of model should be influenced by the task in hand, and considerations such as data availability and accuracy, personnel and time constraints.

2.2.1. Supply Shifters

Cassels (1933) concludes the analysis of supply is more complicated and difficult than the analysis of demand. Two decades later, Schultz (1956) argues similarly. While demand depends on fairly constant '*tastes*', the underlying production function that dictates supply depends on fluctuating technologies. Schultz (1956) identifies four important factors contributing to growth in supply of U.S. agricultural output unaccounted for by growth in inputs. None of these factors was appropriately accounted for in previous empirical research: firstly, the specialization of labour; secondly, the closely related improvement of the *quality* of labour; thirdly, inventions and advances in technology; and fourthly, the concept of diminishing returns.

Muth (1964) analyses the derived demand for input factors and the derived supply curve of an industry with constant returns to scale. He shows that output supply is determined by the relative shares of input factors, the elasticities of supply of input factors and the elasticity of substitution between inputs factors. If demand remains unchanged, shifts in output supply are caused by changes in productivity and the supply of inputs.

In Stochastic frontier analysis, the vital assumption is that not all producers are able to optimize production (Kumbhakar & Lovell, 2000). Whether it be minimizing the cost of producing a specified number of outputs, or maximizing output given a set of inputs, there will be variation between firms in the extent to which they are able to efficiently allocate their resources so as to maximize their profits (Kumbhakar & Lovell, 2000).

Diewert & Nakamura (2002) reviews index number methods of productivity growth analysis and some relevant obstacles to appropriate findings. Although productivity and supply are two different concepts, productivity growth is a major factor in long-run increases in supply. Measuring quality change in both inputs and outputs, and obtaining and measuring data appropriately are obstacles to appropriate analyses. A lack of data on expected prices of both inputs and outputs, and the use of proxies for such prices, are threats of bias in such analyses.

Changes in technology are later emphasized by Tomek (1985) who argues improvements in technology are often the most important shifters of supply. Such improvements in technology are notoriously difficult to identify and disentangle from other variables. He notes that while that there have been substantial improvements in the analysis of farm supply in the past three decades, the complicating factors of supply analysis highlighted more than fifty years before his analysis remain important.

The parsimonious approach applied by Marsh (2003) for calculating shifts in demand can easily be applied to supply shifts. Kinnucan & Myrland (2006) computed the supply shift of farmed salmon from Chile in the early 2000s using this procedure. As with the calculation of demand shifts, the procedure only requires price and quantity data, as well as an appropriate supply elasticity measure.

Supply analysis is becoming increasingly sophisticated but methodological difficulties remain. Firm heterogeneity, price expectations, economic inertia in the production process, productivity progress both in the production process and input production, as well as quality changes for all input and output factors all ensure supply analysis is destined to remain complex. While the parametric tool kit is rich, the nature of shifts in supply ensures that no simple solution exists, nor will it ever.

2.3. Defining a Market geographically and in product space

When analysing demand and supply, an appropriate understanding of the market in question is required. A market can be defined as *"…the area within which the price of a commodity tends to uniformity, allowance being made for transportation costs"* (Stigler, p. 85, 1966). Both the *composite commodity theorem* and the *law of one price* are fundamental underlying assumptions in market analysis because they address the issue of defining a market geographically and in product space. The Hicks-Leontief *composite commodity theorem* states that if all prices of several goods move proportionally then the corresponding group of commodities can be treated as a single good. While the theorem requires perfect correlation between prices, this assumption is typically relaxed (Lewbel, 1996). Single goods are usually aggregated into groups to make estimation possible, often after performing statistical tests for whether the *composite commodity theorem* holds. The *law of one price* derives from the assumption that no arbitrage possibilities exist. When the *law of one price* holds for a group of prices in different locations, they move proportionally to each other over time, and we conclude that markets for that group are integrated.

2.4. Measuring the impacts of supply and demand shifts

While computing shifts in demand may be of interest in its own right, the objective of demand and supply analysis is often to measure the impacts of exogenous changes in demand and (or) supply on equilibrium prices and quantities. The impact of shifts in supply and demand on prices and quantities can be determined in a framework commonly known as an Equilibrium Displacement Model (EDM). EDMs have a prominent place in applied economic analysis and have been used to evaluate policy issues at least since Hicks (1932). EDM is a comparative statics framework expressed in elasticity form. Comparative statics, as EDMs, describe the movement from one equilibrium to another, resulting from a displacement in one or more of the parameters in a system of equations. An EDM is derived through expressing a set of supply and demand functions in reduced form (i.e. in terms of endogenous variables such as price and quantity), and computing the impact of exogenous supply and/or demand shifts on the endogenous variables. EDMs are locally linear approximations of the true supply and demand functions in terms of relative changes and elasticities. This implies the results from EDMs are more precise for small changes in equilibrium. For instance, see Wohlgenant (2011) for an introduction to EDMs and a review of their precision. Muth (1964) was the first to express a system of a single output with two input factors of production in reduced form. He derived the demand for input factors and the derived supply of output as well as the impact of equilibrium prices and quantities from shifts in demand, productivity, and input supply. Floyd (1965) applies Muth's framework to calculate the effects of agricultural farm price supports on return to labour and land. Gardner (1975) investigates the impacts of shifts in supply and demand on the retail-farm price ratio and the farmers' share of the consumer food dollar, finding that mark-ups change in different ways depending on the source of shifts in equilibrium prices and quantities. Extensions of the framework include linkages to trade in the final output and factor inputs (see e.g. Sumner & Wohlgenant, 1985; Zhao, Mullen, & Griffith, 2005 and references cited therein). Kinnucan & Myrland (2006) calculate the impact of supply expansion from Chile on world salmon prices, trade flows, and producer welfare.

All three papers that comprise my thesis apply empirical research to the world market for farmed salmon. The following section provides an overview of the history of the salmon market and a review of relevant literature on the subject matter.

3. Supply and demand of farmed salmon

3.1. A short history of farmed salmon

Over the last few decades, aquaculture has been one of the fastest-growing animal-based food production technologies (FAO, 2012). In the next decade total production from capture and aquaculture is expected to exceed that of beef, pork or poultry (FAO, 2012). Salmon aquaculture has grown faster than aquaculture in aggregate, from a production of a few thousand tons annually in the early 1980s to over 1.6 million tons in 2011. More than 90 percent of farmed salmon production consists of Atlantic salmon; other species such as trout, coho and sockeye are produced in smaller quantities. Between 1980 and 2000 there were significant growth in quantities and falling prices, indicating substantial supply growth. Since 2000 both salmon prices and price volatility have increased (Øglend & Sikveland, 2008; Øglend, 2013). At increasing volumes, this suggests demand has outpaced supply growth.

Production of salmon is optimal at a water temperature of around 13 degrees Celsius (Thyholdt, 2014). At higher temperatures, the mortality rate increases, while growth rates become very low at temperatures substantially below 13 degrees. The potential production sites of salmon production are therefore limited and the industry is concentrated in a few countries. The major producing countries of farmed salmon are Norway, Chile, Scotland, Ireland, Canada and the Faroe Islands, which combined constitute nearly 100 percent of all farmed salmon globally. Norway is the largest producer, with about 60 percent, and Chile has about 25 percent of global salmon production.

Farmed salmon is a globally traded commodity. The largest markets have traditionally been the EU, the U.S. and Japan. The EU and the U.S. are responsible for about 50 percent and 25 percent of total global salmon imports. In the last decade, Russia and Brazil have seen a vast increase in salmon imports and these five regions now account for about 88 percent of global salmon imports. Emerging countries in South East Asia are also seeing marked increases in salmon imports.

The market for salmon has gradually expanded since its inception. Downward pressures on prices created incentives to expand markets geographically and through an increased variety of processed salmon products. Stable supply at relatively low prices has given rise to an increasingly large processing industry producing value-added products. The increased prevalence of supermarkets beginning in the late 1980s provided an excellent match for the salmon farming industry because of its capacity to provide salmon consistently throughout the year. The possibility for supermarkets to know likely availability months in advance gives farmed salmon a competitive advantage over wild fish, where supply is inconsistent and varies in quality and size. This is also reflected in the salmon producer’s share of the retail price, which hovers around 50 percent, compared to Norwegian fishermen who receive between 10 and 15 percent of the retail price of cod sold in the UK (Asche & Bjørndal, 2011).

3.2. Salmon Supply

Asche & Bjørndal (2011) provide an overview of the development of productivity growth and technical change in the production of farmed salmon. Improved technologies and increased control of the production process have been the main factors contributing to the large increase in salmon production since the early beginnings in the 1980s. Reduced production costs between 1980 and 2010 has resulted in a significant decrease in cost of production. In 2008, prices were 30 percent of what they were in 1985, while production costs were around 28 percent. Due to data availability, the literature on supply and productivity growth of farmed salmon mainly focuses on Norway. Average profit margins for Norwegian farmers have remained fairly constant but have shrunk or turned negative in periods when there were disease problems or large price declines. In Chile production has varied considerably in the 2000s due to rapid production growth followed by serious disease problems, and subsequent efforts to boost production (Asche, Hansen, Tveterås, & Tveterås, 2009). In a competitive industry such as the salmon market, one would expect the reductions in production costs to translate directly into reduced prices. Although disease problems and other supply constraints influence short-term volatility of salmon prices, the price in the long-term is heavily influenced by production costs. Both productivity growth in terms of more efficient use of inputs and higher quality of inputs (e.g. feed, smolts and labour) have contributed to the reduction in salmon prices since the early 1980s.

Increasing returns to scale has been important for reducing costs of production. The average production per farm has increased almost twentyfold from 1982 to 2008, from about 47 tons to 904 tons. Asche & Bjørndal (2011) suggest the potential for further economies of scale may be extracted. As in other efficient food-production sectors, the cost of feed is relatively high at about 54 percent in 2008, doubling from about 27 percent in 1987. Guttormsen (2002) finds that the technology has improved so much that the substitutability between input factors (e.g. feed and labour) is approaching zero, implying that salmon farming is becoming a fixed-factor proportions industry. The supply of salmon is thus very much dependent on the supply of inputs, and increasing costs of input factors translate directly into increased production costs. This has been the case in the last few years, with both increasing feed and production costs.

The production of salmon is restricted by governmental regulations. Rationales for such restrictions are to adapt production to market demand through a "balanced development" of the industry - and in relation to the capacity of veterinary and extension services, education and research in salmon farming. Environmental concerns are also important. Obtaining a licence is a prerequisite for producing salmon in all salmon-producing regions. The licensing regimes constrain the maximum production for each production site and for the industry as a whole. Norway introduced feed quotas in 1995, limiting the amount of feed use per year on a farm. In 2005, the feed quota system was abolished and replaced by a restriction on maximum allowable standing biomass per licence. The regulatory regimes for salmon production vary by country but every country restricts production capacity. The constraints imposed by government restrictions and the fact that substitutability between inputs factors is approaching zero suggest salmon supply is highly inelastic, at least in periods where price is substantially higher than production costs. Empirical analyses of salmon supply find that salmon supply is highly inelastic in the short run but relatively elastic in the long run (Andersen, Roll, & Tveterås, 2008; Asheim, Dahl, Kumbhakar, Øglend, & Tveterås, 2011).

In Norway, vast productivity growth has ensured production has continued to grow much faster than the number of fish farm licences since the early 1980s. Asche, Guttormsen, & Nielsen (2013) and Vassdal & Holst (2011) find that productivity growth did not increase significantly during the 2000s. Vassdal & Holst (ibid.) suggest that improvements of best practice production technologies are becoming increasingly hard to achieve. While the catch-up effect of producers operating less efficiently may continue to improve average performance for some time, Vassdal & Holst's (2011) results indicate a slowdown in the long-run productivity growth. Asche et al. (2013) suggest salmon farming has developed into a mature industry with lower growth rates. They suggest that since the late 1990s increases in the use of inputs has been the major factor for the increases in production, made possible in particular by increasing the size and number of production sites. If this is the case, the availability and prices of input factors may be the determining factors for the development of salmon production in the future.

With little or no productivity growth, regulatory restrictions and number of new licences awarded in the future will dictate production. The number of new licences may be limited due to environmental and political concerns, or due to limited availability of potential production sites. In Scotland, Ireland and Canada the potential sites for salmon farming appear to have already been exhausted due to a combination of biological factors and environmental concerns. If demand continues to grow as quickly as it has been during the last decade, regulatory restrictions on production may cause the price of salmon to become detached from production costs. If the number of licences is not increasing to keep up with future demand growth the value of licences will increase, with commensurate high salmon prices. A significant long-run positive deviation between price and production costs would give strong incentives for innovations to increase production. It remains to be seen if the price of salmon will approach that of production costs through the introduction of competing products and a subsequent decline in demand, or whether innovations in the salmon farming industry will permit supply to meet future demand growth. Alternatively, government regulations and the number of new licences issued may be adjusted so that supply can keep up with demand growth.

3.3. Salmon Demand

There has been significant research on demand for salmon. Studies using older data has typically found demand for salmon to be elastic (Asche, Salvanes, & Steen, 1997; Bjørndal, Salvanes, & Andreassen, 1992; DeVoretz & Salvanes, 1993), while studies using newer data have reported lower elasticity. Recent studies using data between late 1990s and 2010 report own-price elasticity values between -0.2 and -1.7, with a mean and median around -0.75 (Asheim et al., 2011; Chidmi, Hanson, & Nguyen, 2012; Davis, Lin, & Yen, 2007; Fousekis & Revell, 2004; Hong & Duc, 2009; Jones, Wozniak, & Walters, 2013; Muhammad & Jones, 2011; Sakai, Yagi, Ariji, Takahara, & Kurokura, 2009; Singh, Dey, & Surathkal, 2012; Tiffin & Arnoult, 2010; Xie, Kinnucan, & Myrland, 2009; Xie & Myrland, 2011). Elasticity values vary by product form, period length, income level and market location. Frank Asche & Bjørndal (2011) suggest demand has become less elastic as the price of salmon has decreased and that demand for salmon may already be inelastic.

Increasing quantities at decreasing prices in the period before 2000 may be solely due to supply expansion, although this does not mean demand remained constant throughout this period. Since 2000, however, the growth in quantities at non-decreasing prices clearly indicates expanded demand. Asche, Dahl, Gordon, Trollvik, & Aandahl (2011) find that demand growth in the EU and France since the early 2000s has been substantial, with average demand growth of 7.6 and 4.7 percent respectively year on year.

The literature on demand growth for salmon has mostly relied on trend indicators such as advertising or time trends (Bjørndal et al., 1992; Myrland, Emaus, Roheim, & Kinnucan, 2004; Xie et al., 2009; Xie & Myrland, 2011). Through a series of studies Kinnucan & Myrland (2000, 2002, 2003) investigated the effects of generic marketing in an EDM framework. While the impact is consistently found to be significant, it is typically very tiny (Myrland & Kinnucan, 2006). The impacts of substitute prices on salmon demand are uncertain. Asche & Bjørndal (2011) note that salmon appears to have won market share at the expense of a large number of products, and the emergence of new product forms appears to have caused significant demand expansion in established markets.

Kinnucan & Myrland, (2005) find the total income elasticity in world trade for salmon is about one, suggesting that global imports will grow at about the same pace as global income. Other studies have found that salmon is income elastic (Chidmi et al., 2012; Davis et al., 2007; Fousekis & Revell, 2004; Hong & Duc, 2009; Jones et al., 2013; Muhammad & Jones, 2011; Sakai et al., 2009; Tiffin & Arnoult, 2010; Xie et al., 2009). Reported income (expenditure) elasticities for salmon are usually conditional on total expenditure on a group of fish commodities. Since the total expenditure elasticity for fish is usually inelastic

(Muhammad, Seale, Meade, & Regmi, 2011), the elasticity of salmon with respect to total income is lower than conditional expenditure elasticities.

3.4. Defining the market for salmon

In order to analyse a market one must establish its boundaries. A market for an aggregated product requires that the *Law of one price* and the *Composite commodity theorem* must hold. That is, firstly, if a product is sold in different locations, do these different locations constitute the same market, or are they separate? Secondly, do different salmon products constitute the same market? Farmed salmon is a globally traded commodity, produced both fresh and frozen in different weight classes. Extensive empirical analyses have investigated this subject. Market delineation and integration studies have addressed the price relationships between different locations and product forms.

There appears to be no separate market for fresh salmon; the market for fresh salmon is a global market (Asche & Sebulonsen, 1998; Asche, 2001). Different species of farmed and wild salmon have also been investigated and they appear such close substitutes that the *Law of one price* holds (Asche, Bremnes, Salvanes, & Wessells, 1999; Asche, Guttormsen, Sebulonsen, & Sissener, 2005). Constituting a large share of total salmon supply, Atlantic salmon is found to determine the prices for both farmed and wild salmon (Asche et al., 1999). Since wild salmon is mostly sold frozen, this suggests there is also a strong link also between fresh and frozen salmon, and that both are likely to be part of the same market. The share of farmed salmon in salmon supply has been consistently increasing. A recent study by Xie & Myrland (2011) on the French salmon market find that wild salmon constitute a different market niche from farmed salmon. They also find support for Lewbel's (1996) *Composite commodity theorem*. In summary, the literature suggests the salmon market is global, consisting of a relatively homogeneous product.

These characteristics of the global salmon market imply that it is appropriate to analyse the global impacts of regional supply and demand shifts in an EDM framework. Empirical applications of EDMs on the global salmon market are numerous, encompassing issues such as the impacts of various promotions (H. W. Kinnucan & Myrland, 2000, 2002a, 2003), income growth and tariffs (H. Kinnucan & Myrland, 2006; H. W. Kinnucan & Myrland, 2005), exchange rates (H. W. Kinnucan & Myrland, 2002b), and Chilean supply expansion (H. W. Kinnucan & Myrland, 2006). This dissertation follows in the methodological footsteps of these applications. The next section presents a simple example of the supply side of an EDM framework and the decomposition of gross supply shifts, where I determine the extent to which new licences have contributed to the growth in recent years of Norwegian salmon supply.

4. An analysis of the relative impact of new licences on Norwegian salmon supply

If productivity in salmon farming is indeed slowing down, the only substantial potential for increased production must come from increasing use of inputs. Salmon farming is becoming an industry with more or less fixed factor proportions in inputs. That means there is no (or a very small) effect on production from increasing the use of one or more inputs if other inputs levels remain the same. Since the number of production sites is tightly regulated by production licences, governmental restrictions will play a major role in determining the growth of future salmon production. If the use of production sites is at their maximum limits, any further increase in production must come from productivity growth or the issuing of new licences. A simple analysis of the historical impact of new licences on Norwegian salmon supply illustrates the relative importance of government regulations on the development of Norwegian salmon production.

Let salmon supply be determined by own price, the number of licences available, and other unidentified factors:

$$Q_t = Q_t(P, L_{t-2}, Z)$$

Where P is the output price and L_{t-2}, is the number of production licences two years previously. It takes at least two years from the time a licence is issued for normal production to be achieved deriving from that licence, hence current production is restricted by the number of licences available two years previously. Z is a vector of all other factors that influence supply. Taking the total derivative of this function, supply shifts are linearly approximated as follows:

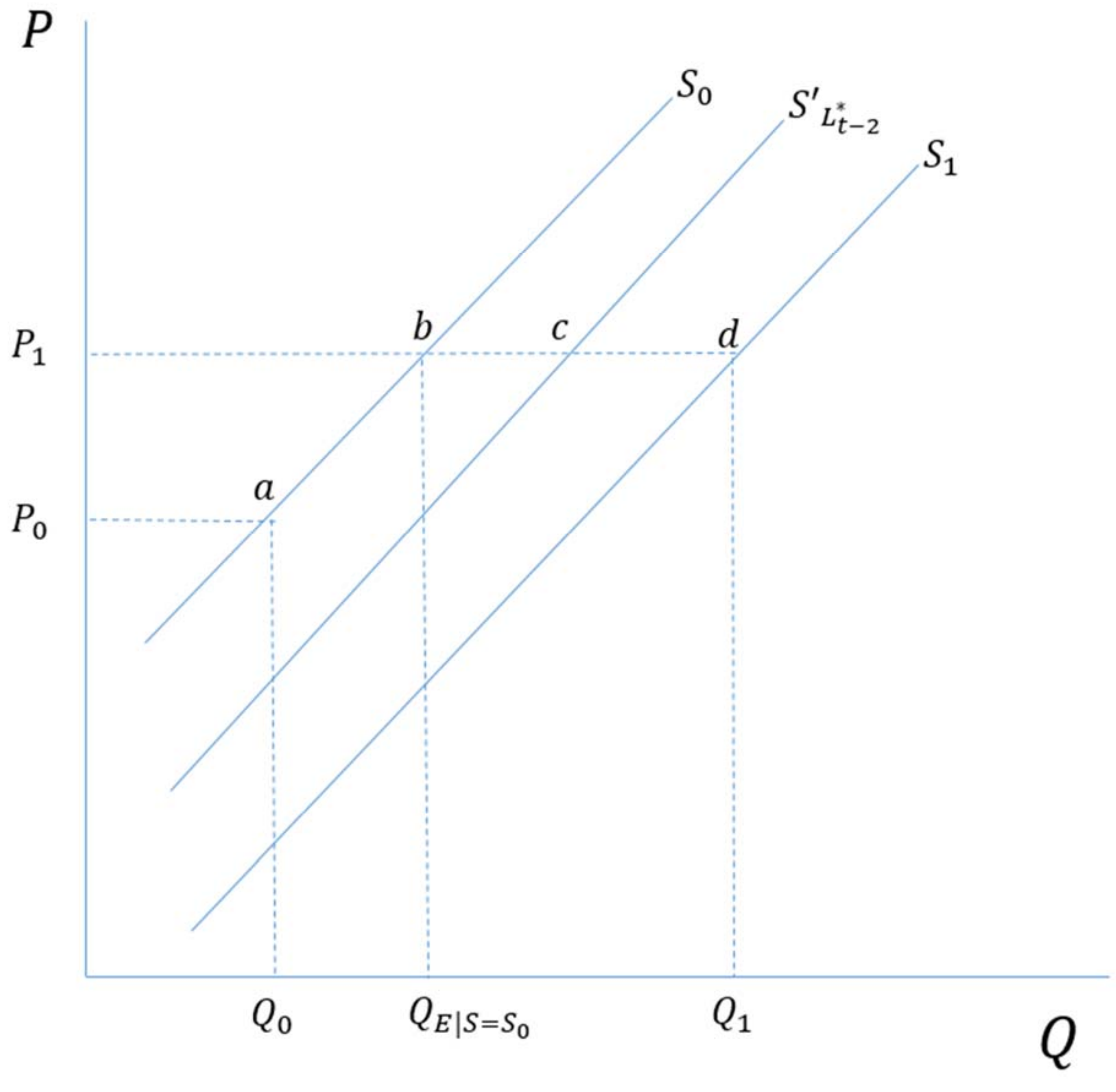
$$\frac{dQ_s}{Q_s} = \frac{\partial Q_s}{\partial P}\frac{P}{Q_s}\frac{dP}{P} + \frac{\partial Q_L}{\partial L}\frac{L}{Q_L}\frac{dL_{t-2}}{L_{t-2}} + \frac{\partial Q_s}{\partial Z}\frac{Z}{Q_s}\frac{dZ}{Z}$$

Or

$$Q^* = \varepsilon P^* + \epsilon_L L^*_{t-2} + r'$$

Where ε is the own-price elasticity of supply, ϵ_L is the elasticity of supply with respect to new licences, and r' is the shift in supply caused by factors other than changes in the number of licences issued. Asterisks denote relative changes. The total shift in supply between two periods is illustrated as follows:

Figure 1. A supply shift due to new licences and other factors[1]



Where S_0 and S_1 denote the supply schedules in years *0* and *1*, and $S'_{L^*_{t-2}}$ denotes the supply schedule in year 1 where only the increase in the number of licences is taken into account. If

[1] The supply schedules are linear only for illustrative purposes.

we assume no shift in supply between year 0 and 1, we retrieve the expected quantity $Q_{E|S=S_0}$ by taking into account the expected impact of the price change on quantity supplied. The expected change in quantity is given by the price-induced movement along the original supply schedule from points a to b. The distance between b and c is the supply shift due to the issuing of more licences two years previously, while the distance between c and d is the supply shift due to other factors. The total shift in supply between the two periods is the aggregate of these two effects, measured by the horizontal distance between the actual quantity level in year 1 Q_1, and the expected quantity level $Q_{E|S=S_0}$, or between points b and d. We can determine the size of each specific shift by using data on price and quantity changes between the two periods and the appropriate elasticity values.

If all new licences are of the same quality and size as existing ones, the impact of a one percent increase in the number of licences should be a one percent increase in supply. If this is not the case, differences in qualities and size between existing and new licences must be taken into account. For simplicity, we assume all new licences are of the same quality and size as existing ones, and set $\epsilon_s = 1$. This gives the following expression:

$$Q^* = \varepsilon P^* + L_{t-2}^* + r'$$

We set ε to 0.05, in accordance with Andersen et al's (2008) short-run elasticity of supply for Norwegian salmon. Such a low elasticity of supply accords with the notion that salmon farming is approaching fixed-factor proportions and that the number of available production sites is a restrictive factor for increased production. Historical data for prices, quantities and the number of licences issued between 1996 and 2013 were retrieved from the web pages of *The Norwegian Directorate of Fisheries*. To analyse the impact of new licences on Norwegian salmon supply we can compare the total shift in supply that occurred during the period between 1999 and 2013 to the shift in supply that would have occurred if no new licences were issued[2]. The shift in supply due to other factors than new licences is calculated as follows:

$$r' = Q^* - \varepsilon P^* - L_{t-2}^*$$

[2] We assume that the change in licences issued between 1996 and 1997 does not have an effect on supply until 1999, hence 1999 is the first year where we compute supply shifts.

Note that the size of this shift is dependent of the value of the elasticity parameter. The total shift in supply S^* is the combined effect of new licences L^*_{t-2} and other factors influencing supply r':

$$S^* = L^*_{t-2} + r' = Q^* - \varepsilon P^*$$

Running this model for consecutive years provides the annual effects of licensing and other factors on the total supply expansion of Norwegian salmon. The cumulative impacts of licences were retrieved by comparing the total shift in supply between 1999 and 2013, which we denominate as $\prod_{1999}^{2013} S^*$, with the shift in supply that would have occurred had no new licences had been given, denominated $\prod_{1999}^{2013} S^*_{NoLi}$.

The cumulative total supply shift for each year is calculated as follows:

$$\prod_{1999}^{n} S^* = \left[\prod_{t=1999}^{n} (1 + L^*_{t-2} + r'_t) - 1 \right], n = 1999, 2000, \ldots, 2013$$

The cumulative supply shift that would have occurred had no licences been issued is computed by setting L^*_{t-2} to zero in the formula above. The results are summarized in Table 1.

Table 1. Cumulative supply expansion from 1999 to 2013, with and without new licences

Year	Total cumulative supply shift $\prod_{1999}^{n} S^*$	Cumulative supply shift with no new licences $\prod_{1999}^{2013} S^*_{NoLi}$	Relative impact of new licences on total supply shift $\frac{\prod_{1999}^{n} S^* - \prod_{1999}^{n} S^*_{NoLi}}{\prod_{1999}^{n} S^*_{NoLi}}$
1999	15 %	15 %	3 %
2000	17 %	16 %	8 %
2001	25 %	21 %	18 %
2002	35 %	29 %	19 %
2003	43 %	38 %	13 %
2004	54 %	49 %	11 %
2005	56 %	48 %	17 %
2006	65 %	46 %	39 %
2007	98 %	76 %	29 %
2008	98 %	76 %	29 %
2009	123 %	97 %	27 %
2010	130 %	106 %	23 %
2011	164 %	120 %	37 %
2012	210 %	157 %	33 %
2013	181 %	133 %	36 %

Supply would have expanded by 133 percent between 1999 and 2013 had no new licences been issued. The new licences caused supply of Norwegian salmon to expand by an additional 36 percent, to a total supply expansion of 180 percent[3]. New licences thus appear to be an important factor in explaining the supply expansion of Norwegian salmon. However, the combined effect of other factors such as economies of scale, shifts in input supply, and technology improvements on inputs and production is substantially higher. An important underlying assumption of this analysis is that the introduction of new licences did not influence the levels of other factors that cause supply to shift. It is beyond the scope of this analysis to investigate this assumption, and the results must be interpreted with this in mind.

This simple analysis illustrates how the impact of one or more specific factors on shifts in total supply (or demand) can be determined through simple approximations to the unknown supply (or demand) curve. The size of residual, unexplained shifts is also determined. In a complex world where numerous variables are near impossible to quantify, this approach presents an alternative to traditional measures of shifts in supply or demand. The papers of my thesis follow similar procedures by determining the size, causes and price impacts of supply and demand shifts in the global salmon market

5. Summary of the papers in the dissertation

This dissertation consists of three papers, all focusing on the global market for farmed salmon. The first paper uses the approach by Marsh (2003) to determine annual relative shifts in demand in different salmon-consuming regions. The second paper extends this procedure by determining both demand and supply shifts in the global salmon market. These shifts are applied to an EDM to determine the relative impacts of every regional supply and demand shift on price formation. The third paper extends the procedure of the first, using a broadly similar approach to the example given in the previous section for supply shifts. We decompose total demand shifts into three parts; the impact of changes in substitute prices, income, and the residual demand shift due to other factors. While each of the three papers of this dissertation represents individual contributions to the literature, they are strongly interlinked, both methodologically and empirically.

[3] A more thorough analysis could take into account the change in the regulatory regime in 2005. Before 2005, feed quotas were imposed, while after 2005 there have been regulations on maximum allowable standing biomass per licence.

5.1. Summary of Paper 1: The Bumpy Road of Demand Growth – An Application to Atlantic Salmon

Since 2000, salmon prices have been volatile and slightly increasing (Øglend & Sikveland, 2008; Øglend, 2013). In this period the market has expanded both geographically and by way of an increased variety of product forms. At increasing volumes, this suggests demand growth has been outpacing supply growth. These recent developments encourage further investigation of demand in different salmon-consuming regions. As salmon is a globally traded commodity, it is an ideal product for measuring demand growth in all major importing regions. In this paper we use an adjusted procedure of Marsh's (2003) approach for measuring shifts in demand. We define a shift in demand as the percentage shift in quantity demanded at a given price. Asche et al. (2011) applied Marsh’s procedure to the EU and French markets: we extend it to all major salmon-importing regions of the world in the period between 2002 and 2011. We also perform a sensitivity analysis to examine the impact of the choice of elasticity parameters on the computed demand shifts. The results show substantial variation in demand growth, both between regions and over time. Emerging markets such as Russia and Brazil exhibit the highest growth in demand for salmon, experiencing average annual increases of approximately 20 percent. The U.S. and Japan have the lowest growth in demand, with an average of about three percent a year. The EU has an annual average demand growth of approximately nine percent a year. Total global growth in demand from 2002 to 2011 was approximately 94 percent - or around eight percent a year. Furthermore, demand does not grow smoothly. There were several periods of negative demand growth in every region examined. While the inclusion of a trend variable in a demand analysis would be able to capture the long-run trends, the year-on-year variation in demand is so large that a trend variable would not be able to explain or predict short-term shift in demand. The sensitivity analysis confirms overall patterns. We perform 10,000 simulations using different values for the elasticities of demand and recalculate the demand shifts for each simulation. The results indicate that levels of demand growth in Brazil and the EU are the most uncertain. Five and 95 percent percentiles for average annual demand growth are 13.5 and 25 for Brazil, and 3 and 11.7 percent for the EU. The percentiles for the average annual global growth are six and 10 percent. In other words, global demand growth for salmon has been in the region between six and 10 percent annually from 2002 to 2011.

5.2. Summary of Paper 2: Disentangling supply and demand shifts: the impacts on world salmon prices

Since the early 2000s, many food commodity prices have increased drastically. This development has led to extensive research, much of it pointing to general trends that may explain the general price increases of food commodities (Enders & Holt, 2012; Gilbert, 2010; Pingali, 2007; Serra & Zilberman, 2013; Trostle, 2008). However, the price developments vary considerably for different food commodities and commodity-specific effects are obviously important. This paper extends the approach of the first. I computed yearly shifts in both demand and supply for each major salmon-producing region using the same approach as in the first paper. In terms of supply, I examined Norway, Chile, Canada, UK/Ireland, Faroe Islands and Rest-of-the-World (ROW); in terms of demand, I looked at the EU, the U.S., Japan, Russia, Brazil, and Rest-of-the-World (ROW)[4]. The computed supply and demand shifts were applied as exogenous variables in an EDM of the world market for salmon. This procedure allows the decomposition of annual shifts in prices and quantities between the relative impacts of shifts in demand and supply for each importing and exporting region. Typically, an EDM computes the impact of one or more specific variables on price and quantities, suppressing all other variables. In my paper, I compute the yearly regional aggregate impacts of demand and supply shifts caused by *all* variables affecting demand and supply.

The results indicate a large variation in demand and supply growth both over time and between regions. Supply growth from Norway has the largest negative impact on price with an annual average impact of negative 4.5 percent from 2002 to 2011. The average impacts of other salmon-producing regions are not statistically different from zero. The variance of Norwegian supply shifts is significantly smaller than the variance of supply shifts in all other salmon-producing regions. This suggests some structural differences between Norway and other regions. In Chile, the variance of supply shifts and price impacts are particularly large. This is not surprising, given that country's substantial production increase in the early 2000s, and subsequent disease problems that have occurred (Asche et al., 2009). On the demand side, the average demand shifts and price impacts are significantly different from zero only for Russia and ROW. The fact that only two regions expressed average demand shifts statistically different from zero does not indicate demand for salmon is stable or unchanged in all other regions. Large standard errors of demand shifts for all regions suggest annual demand shifts

[4] ROW countries for exporters consist of net exporters, while ROW for importers consist of net importing countries.

vary substantially from year to year. Even though not statistically significant, the largest average annual price impact comes from the EU, with a positive price impact of 2.2 percent a year. While the EU demand growth still has the largest impact on price, low growth rates in the U.S. and Japan imply price impacts on these markets are close to zero on average. As the emerging regions' share of the total market increases, their impact on price is becoming larger. I also test for cumulative impacts of successive positive or negative supply and demand shifts, and detect price impacts in all but one region (Canada). This indicates that the year-to-year variation in demand and supply shifts is so large that one must expect annual supply and demand shifts in almost every exporting and importing region to impact salmon prices. For any market with unstable price behaviour, the procedure presented in this article could prove a useful instrument for determining the relative impact of supply and demand shifts on price.

5.3. Summary of Paper 3: 'The Demands They Are a-Changin'

This paper extends the procedure of the first. We show that when data and appropriate elasticity values are available, we can decompose the gross shift in demand between the impact of specific variables and the residual demand shift caused by unaccounted-for variables. This approach still permits demand to vary independently between periods, while quantifying the impacts of any variable of interest where data is available. By disentangling the impact of economic factors like changes in relative prices and income, the impact of non-economic factors is determined. This provides an alternative to the use of trend indicators for measuring demand shifts caused by such factors. We apply this procedure to all major salmon-importing regions from 2002 to 2011. The results indicate, as in the first paper, a substantial variation in demand growth both over time and between regions. The average residual shift in demand accounts for more than half of the total demand shift in every region except Russia. This suggests changes in income and relative prices account for less than half of the recent growth in salmon demand. The standard errors of the residual demand shifts are large for all regions. This indicates unexplained shifts in demand are unsystematic; therefore, using time trends to capture unexplained demand shifts is inappropriate for explaining year-on-year shifts. The large residual demand growth and standard errors suggest further research is necessary to understand the reasons behind development of the demand for salmon. The results also demonstrate that any demand analysis focusing only on relative prices, income and a trend variable will not appropriately account for the large variation in salmon demand in any region.

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