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Value Chains for Primary Goods:
From Wild to Farmed Fish

by

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April 2003

Norges Handelshøyskole

ISBN 82 - 405 - 0093 - 5

Contents

Preface *iii*

Introduction 1

Background 7

Theory and Method 15

Empirical Findings and Policy Implications 20

Papers

1. Aggregation over different qualities: Are there generic commodities? 27

2. On the relationship between aquaculture and reduction fisheries 39

3. Market Integration and Exchange Rates in Primary Commodity Markets 69

4. Forecasting Commodity prices with switching regimes: A MS-VAR approach for fish meal price 97

5. Fish Meal Demand from Livestock and Aquaculture: Inference Using a Shrinkage Estimator for Panel Data 117

6. Norwegian Salmon Aquaculture and Sustainability: The Relationship Between Environmental Quality and Industry Growth 153

Preface

For my dissertation the committee has consisted of Prof. Trond Bjørndal, Norwegian School of Economics and Business Administration, Prof. Frank Asche, Stavanger University College, and Prof. Lars Mathiesen, Norwegian School of Economics and Business Administration. In addition a number of people have provided valuable suggestions, encouragement and inspiration during the work with the dissertation.

In the role as my main advisor, Professor Trond Bjørndal, has guided me through critical stages of my dissertation, seeing yet another Tveterås through the process. He has helped me to set limits to my research and to keep focus, but giving me room to embark on detours that make the experience more fun. His advice and suggestions have undeniably been beneficial, leading to tighter and more self-contained end product.

Having an office close to Professor Frank Asche's has led to many inspired hours of discussions, being generous with his time as he is. The dissertation would not have been where it stands without his valuable suggestions and comments. Moreover, he has a terrific ability to provide encouragement and clear-headed suggestions when my own head have been clouded with problems at hand. His cheerful presence has made the work all the more enjoyable. Frank is co-author on two of my papers

Professor Lars Mathiesen entered the advisory committee at later stage, but with his suggestions he has managed to put his mark on the dissertation. In particular he introduced me to the idea of a kinked fish meal demand, which is the main concern in two of my studies.

My brother Ragnar Tveterås also deserves richly credit, supporting me in every imaginable way; from brotherly support to co-authorship with one of the papers in the dissertation, and being generous with his time.

I am grateful to Professor Jon Conrad who arranged my stay at Cornell University, and who made my stay there instructive and enjoyable.

It has been a pleasure to share office with Ola Kvaløy, fellow student and friend whom I've shared hours of discussions on economics and unrelated matters, accompanied with many cups of coffee.

Professor Petter Osmundsen has contributed to many inspired and enjoyable hours in the small band of economists at Stavanger University College, whom together with Frank, Ragnar and Ola, have made the time here fun.

Interntational Fishmeal and Fish Oil Organisation has provided me with data and additional information. Special thanks to Jean Francois Mittaine.

I am grateful for the Department of Petroleum Technology that has accommodated me with office and equipment here at Stavanger University College, during my three-year period.

I also want to thank the Department of Applied Economics and Management at Cornell University where I stayed for a year. They accommodated me with office space and gave me the opportunity to visit many interesting lectures in addition to a number of other activities.

The Research Council of Norway has provided me with the three-year doctoral grant as project no. 24445, of which I am very grateful. The Research Council supported me with additional funds for me stay at Cornell University.

Finally, I want to thank my mother and father, whose support and love has been of great help.

Stavanger, April 14, 2003

Sigbjørn Tveterås

1. Introduction

This thesis investigates several important empirical issues related to the value chain for farmed salmon. Both the higher and lower end of the value chain receive attention, from the fish meal market further down to the markets for salmon products. The main focus is however on the fish meal market as a supplier of terms for salmon aquaculture, as fish meal is the main protein source in salmon feeds.

Aquaculture has experienced an explosive growth over the last few decades, driven by the development of intensified production systems. The rapid expansion of intensive aquaculture has caused an increasing pressure on markets for marine raw materials. In particular, the limited availability of fish meal for aquaculture feeds, coined the 'fish meal trap', represents a concern.[1] Fish oil is another strategic input which the global aquaculture industry has consumed an increasing share of. Many worry now that the growth in aquaculture production will start to decline, because of the limited availability of marine raw materials. Much attention is devoted to the demand for fish meal, where large changes have taken place following aquaculture's rising fish meal consumption. The salmon farming industry receives particular attention, as the leading aquaculture consumer of marine raw materials.

Farmers of carnivorous species like salmon prefer fish meal to vegetable protein sources, since marine proteins satisfy essential nutritional requirements of farmed fish. The same case can be made for fish oil. The combination of aquaculture's growth and its preferences for marine raw materials have made for some gloomy projections. Two studies project increased scarcity of fish meal and fish oil. New and Wijkstrom (2002) project that aquaculture will consume all available fish oil supplies well before 2010, while the aquaculture sector will

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[1] See e.g. Naylor et al. (2000), Waagbø, Torrison and Austreng (2001), New and Wijkstrøm (2002), Tuominen and Esmark (2003).

consume the entire fish meal supply around 2020. Waagbø, Torrissen, and Austreng (2001) operate with a slightly shorter time span, but are still fairly similar to New and Wijkstrom, with fish oil hitting the mark at 2005 and fish meal after 2010. In economic terms the projections imply that prices will increase sharply over the next 5 to 15 years, reflecting the growing scarcity of fish meal and fish oil.[2]

This development is worrisome, as aquaculture contributes to an increasing gross supply of fish during a time where traditional fisheries stagnate and the number of overexploited fisheries increase.[3] Figure 1 shows aquaculture's increasing share of total seafood supply from 1950 to 2001, in addition to a diminishing growth rate for capture fisheries. However, farmed fish production has not been able to counter a decreasing availability of fish per capita. Worldwide fish per capita has been reduced from 14.6 kg in 1987 to 13.1 kg in 2000.[4] The use of wild fish in aquaculture feeds can be an explanation why fish farming has not been able to offset stagnating fisheries. The industrial fisheries, i.e., fisheries targeted for fish meal and fish oil production, account for around a third of global capture fisheries. Consequently it is unclear to what degree aquaculture is a net contributor of fish, with the large quantities of wild fish directed for use in feeds. Another source of rising demand for seafood, besides population growth, is income growth in developing countries, particularly in Asia.[5] With the current global development in population and per capita income it is doubtful that demand for fish will stagnate. On the contrary, demand seems to be increasing steadily, providing both opportunities and challenges for aquaculture.

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[2] One can always criticise such projections for being based on unreasonable assumptions, as they use current trends to extrapolate 10 to 20 years into the future. For example they are prone to underestimate the substitution effect (if accounted for at all) that follows with rising raw material prices; rising prices will induce more innovation in feed technology, which should contribute to a larger degree of substitutability between marine and vegetable feed ingredients. However, one can envisage that these researchers wish to induce innovations sooner rather than later, so that their projections prove wrong.

[3] FAO (2002), pp 23.

[4] FAO (2002), pp 3.

[5] Delgado, Crosson, and Courbois (1997).

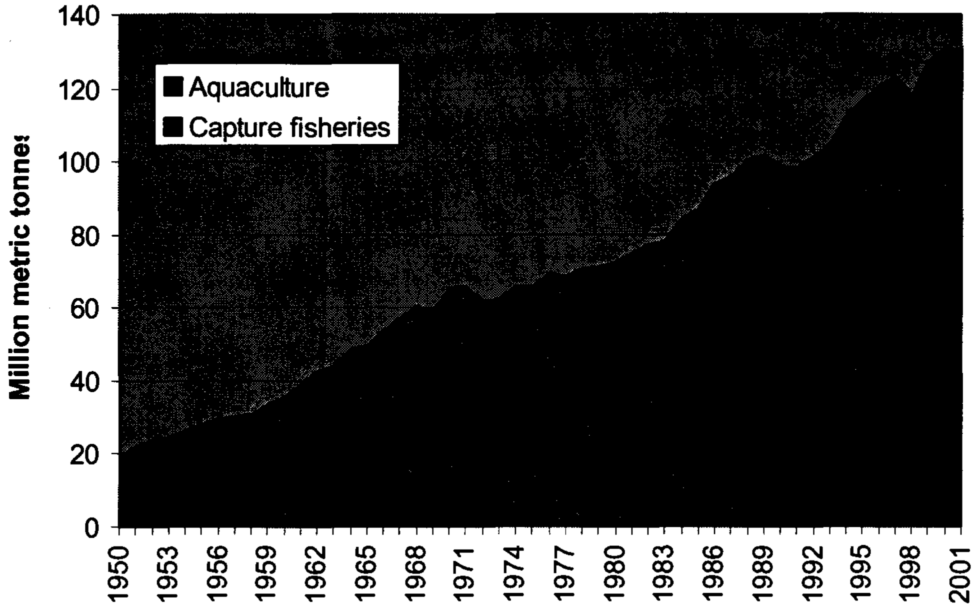

Figure 1. Aquaculture and Capture Fisheries 1950-2001 (Source: FAO Fishtat, 2001)

The issues of fish meal and fish oil scarcity are both important, and deserve a separate treatment. This thesis focuses primarily on fish meal. It is recognised, however, that for several species fish oil scarcity represents at least as big a challenge as fish meal. Furthermore, the supply of fish meal and fish oil is highly inter-linked, since these commodities are largely produced from the same stocks of wild fish.

A subordinate topic in the thesis is econometric modelling of heterogeneity, focusing on some of the trade offs that can be associated with such approach. Two studies in the thesis use heterogeneous models, one with heterogeneity over time and the other with heterogeneity across individuals. Another subordinate topic is more generally on primary goods markets. Fish markets share many features with other primary goods markets, consisting of products that require minimal processing and are fairly homogenous. In this study, the attention in relation to primary goods is on using analyses of price relationships to investigate market structures. The extensive use of such approach in applied economics is both due to the availability of price data and to the information prices contain about market conditions. Four out of six studies in this thesis investigate the fish meal market and markets for salmon products by analysing relationship between prices.

The first study is concerned with how one can use relationship between prices to determine whether goods are homogenous. Aggregation over goods is always an issue in empirical analysis. However, while the problem of aggregation over different goods often is analysed, little attention has been given to the properties of generic goods such as e.g. coffee, wheat and salmon. Often these generic commodities contain a number of different qualities. In this paper a test for aggregation based on Lewbel's Generalized Composite Commodity Theorem (GCCT) using only price data is used to validate aggregation. With the assistance of augmented Dickey Fuller tests for unit roots, we show that the generic term salmon can be used for different weight-classes of salmon.

The next study focus on the relationship between aquaculture and reduction fisheries. Traditional aquaculture has to a large extent used herbivore species with limited requirements for additional feeding. However, in intensive aquaculture production one farm carnivore species like salmon and also feeds herbivore species with fishmeal as this increases growth rates. This has lead to a growing concern that increased aquaculture production poses an environmental threat to the species targeted in reduction fisheries as increased demand increase fishing pressure. In this paper we address this question along two lines. First, under which management regimes may increased demand pose a threat to the species in question.

Second, we investigate what is the market for fishmeal using multivariate cointegration tests. Is fishmeal a unique product or is it a part of the larger market for oilmeals which includes soyameal? This is an important issue since the market structure for fishmeal is instrumental for whether increased aquaculture production may affect fishmeal prices, and thereby increase fishing pressure in industrial fisheries.

In the third study we again return to a more general issue of price relationship analyses, but with specific applications to fish meal and salmon markets. In more recent market integration studies exchange rates have been conspicuous by their absence. In this paper we revisit the work of Richardson's (1978) that addresses the issue of exchange rate pass-through together with market integration in international trade primary goods. With a multivariate cointegration framework using only goods prices and exchange rates it is possible to get relatively rich information, such as exchange rate pass-through, market integration, the law of one price, price leadership, and exogeneity of exchange rates, differing from that of the exchange rate pass-through research on manufactured goods markets. We provide empirical examples using high-valued frozen salmon in Japan and fishmeal exports from Peru to Germany.

The fourth and final of the price relationship studies introduces time dependent heterogeneity. The objective of the study is to present a parsimonious forecasting model for the fishmeal price. The focus is on the soybean meal market's impact on the fish meal price through the soybean meal futures price together with the stocks-to-use as an indicator of demand and supply conditions. A salient feature of the fishmeal market is the impact of El Niño events on fishmeal supply. This possibly leads to two different price regimes, one where the fish meal price is highly correlated with the soybean meal price, and another, during El Niño events, where fish meal supply is low and the fish meal price is not strongly correlated with the soybean meal price. The results from the Markov-switching autoregressions indicate two price regimes where one is mostly governed by the soybean meal price while the other is governed by the level of stocks-to-use.

In the fifth paper, the focus is on inference, where we estimate a panel data model of derived demand for fish meal using a shrinkage estimator for major fish meal importing countries. There are few studies using heterogeneous shrinkage estimators for panel data analyses, and existing ones differ in their view regarding the performance of shrinkage estimators relative to standard pooled and single equation estimators for panel data. The derived demand model estimated by OLS produces implausible elasticities for some countries, while shrinkage estimates are generally reasonable. According to standard asymptotic tests the precision of predictions is substantially higher for a shrinkage estimator than for the OLS country-specific estimates and pooled estimators. When the theoretically more appealing bootstrap method is used for inference, confidence intervals become much wider. Bootstrap confidence intervals generally fail to provide statistical support for the sign of the shrinkage elasticity estimates, although OLS estimates suffer even more in this process. According to the empirical results from the shrinkage model fish meal demand is in general inelastic in own price and highly inelastic in salmon output, leading to a somewhat mixed picture with respect to the effects of growth in salmon production.

Finally, in the sixth paper, we turn to another challenge facing salmon aquaculture, the environmental issues. More generally the paper discusses the relationship between industry growth and environmental quality, but in the context of salmon aquaculture. It is argued that industry growth can reduce pollution by inducing more technological innovations for industry-specific pollution-reducing inputs. This increases the elasticity of substitution between conventional factors of production on the one hand, and pollution on the other, and therefore enables a greater degree of internalization of environmental problems. Four indicators of pollution are examined for Norwegian salmon aquaculture. It is found that the salmon aquaculture industry is one in which growth is associated with reduced environmental problems not only in relative, but also in absolute terms.

Now we turn to an overview of the remaining sections in this introduction. Section 2 gives a more detailed background on the main issues of the thesis, focusing on the development of the aquaculture industry, conditions in the fish meal market, in addition to environmental issues of salmon aquaculture. In Section 3, attention is turned to theoretical and methodological issues, including a discussion of primary goods markets and the use of analysis of price relationships. Another topic discussed here is econometric modelling of heterogeneity. Section 4 concludes with a summary of the main findings and a discussion of policy implications.

2 Background

2.1 Aquaculture – Focus on Salmon Farming

The growth of intensive fish farming has been spurred by technological innovations, where one has been able to capitalize on many ideas from industrialised livestock production. Aquaculture is now the fastest growing of all animal-producing sectors, with a growth rate that has exceeded 5 % per year during the last three decades. The development has resulted in two distinct economic systems for fish supply, namely aquaculture and capture fisheries. In intensive fish farming property rights are clearly defined within the confines of net cages, and cultivation and management is left to the owner of the enterprise, contrasting the "tragedy of the commons" curse in traditional fisheries.[6] Production technology allows control of the biological process like breeding, feeding, and disease management with medicines and vaccines, thereby avoiding the variability that characterises wild fish stocks. As such the technology driven growth of the aquaculture sector has made modern aquaculture production more alike industrialised poultry production than traditional fisheries.

Not all fish farming are intensive though. Usually one differentiates between extensive, semi-intensive, and intensive aquaculture.[7] Intensive aquaculture can be defined by high concentrations of fish in small enclosures, where the nutritional requirements are satisfied by manufactured compound feeds. In extensive aquaculture the fish farmer does not interfere with the biological life cycle of the fish, except for excluding natural predators and control competitors, and, if semi-intensive, provide additional feed when the supply from the natural environment is not sufficient. The Chinese freshwater carp production, which is the world's largest aquaculture production, falls into the extensive and semi-intensive categories. Modern aquaculture is, however, making its way in China as well, and gradually more of the production is being intensified.[8]

In quantity, intensive fish farming is still small compared with traditional Chinese freshwater aquaculture. Intensively farmed aquaculture species like shrimps and salmons are, however, the most important aquaculture products in international trade. Part of the initial success of salmon and shrimps as aquaculture species was the initially high value of these products. The high value gave producers financial leeway for experimenting and developing new production

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[6] See Anderson (2002).
[7] Bjørndal (1990), Naylor et al. (2000).
[8] Tacon (1994).

technology.[9] One result of the productivity growth has been declining salmon prices as shown in Figure 2, where prices have followed the declining production costs (Asche, 1997). With prices in 2002 varying between Norwegian kroner (NOK) 21 and 27 c.i.f. salmon has gone from a high-price to a mid-price fish product in international seafood markets.[10]

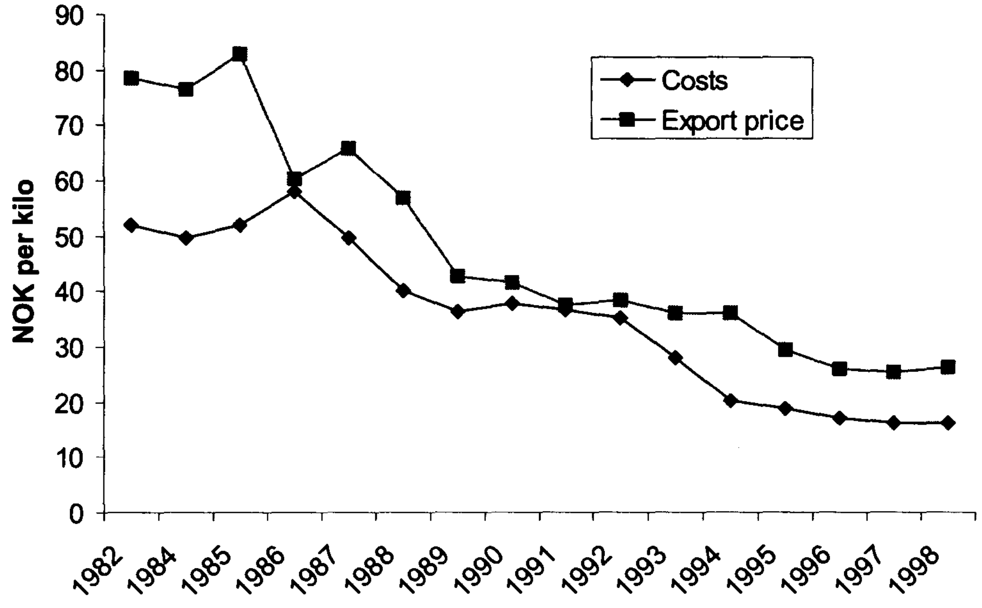

Figure 2. Declining salmon prices and production costs (Source: Norwegian Directorate of Fisheries)

There is a large literature on salmon aquaculture in economics pertaining to virtually all aspects of salmon farming and marketing. The large number of studies likely reflect the economic importance of salmon aquaculture, which in Norway's case, has in only a couple of decades grown from practically nothing to surpass traditional white fish in export value. Only Chile's remarkable growth in salmon production rival Norway's, but also Canada and UK has experienced a rapid of expansion of the industry, as we can see from Figure 3. The common

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[9] Tveterås and Heshmati (2002) give an account of the productivity growth in Norwegian salmon aquaculture through the mid 1980s to the early 1990s, when many of today's practices in salmon farming were established.
[10] FAO (2002), pp 36-37

denominator for the salmon production in these countries is capital-intensive production, as one use costly installations and advanced control systems to run the production.

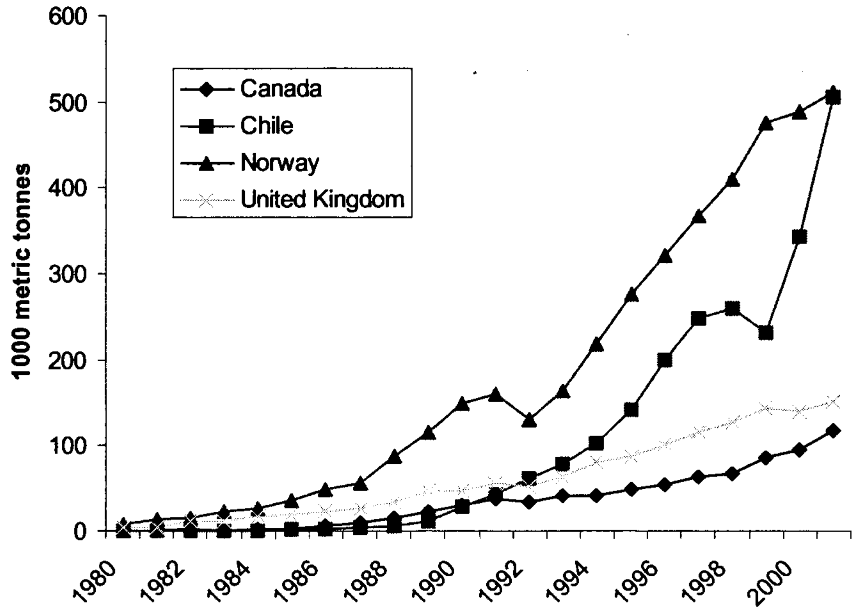

Figure 3. Salmon farming production from 1980 to 2001 (Source: FAO Fishstat)

Fish meal supply does not only represent a resource constraint for the salmon farming industry, but also as a source of variable production cost for salmon farmers. Salmon feed costs account for over 50% of the variable costs, where fishmeal together with fish oil are by far the largest feed inputs in terms of their cost shares (Bjørndal, Tveterås, Asche, 2001). A study by Guttormsen (2002) indicates that substitutability between feed and other inputs in salmon aquaculture is close to zero, and comparing with earlier findings suggests that production technology has changed (Bjørndal, 1990, Salvanes, 1993). Such development emphasises the vulnerability of feed producers and fish farmers to changing raw material prices. It is therefore important with an understanding of the fish meal market, which we now turn to.

2.2 Fish Meal and the Market for Protein Oilmeals

Only a small number of countries have sizable industrial fisheries needed to sustain fish meal production. The fish targeted in industrial fisheries are usually small, bony and oily pelagic species that have low value as food fish. Peru and Chile are the most important industrial fishery nations and also the largest fish meal producers, and together they account for over 50 % of the global fish meal exports. The third paper, "Market Integration and Exchange Rates in Commodity Markets", examines whether Peru by virtue of being the largest export nation shows signs of having market power. The results do not lend support to such hypothesis. The Nordic countries Norway, Denmark and Iceland follow as the second most important group of fish meal producing nations.

The reliance of raw material from industrial fisheries means that fish meal producers cannot respond fully to price changes in the market. The reliance on capture fisheries has also caused an unstable fish meal supply, particularly because of the vulnerability of South-eastern Pacific fisheries to the El Niño weather phenomenon. In Figure 4 the impact of the 1998 El Niño is seen as a marked fall in production in 1998, down 1.1 mmt from 1997's 5.3 mmt. The downfall was even more severe in terms of exports, which were reduced from 4.2 to 2.7 mmt from 1997 to 1998, i.e., a 36 % reduction. If we disregard 1998, fish meal production has stabilised between 6 and 7 mmt during the last 15 years, and considering most of the stocks used for fish are characterised as 'fully fished' it is not likely that fish meal production will increase substantially (WRI, 2001).

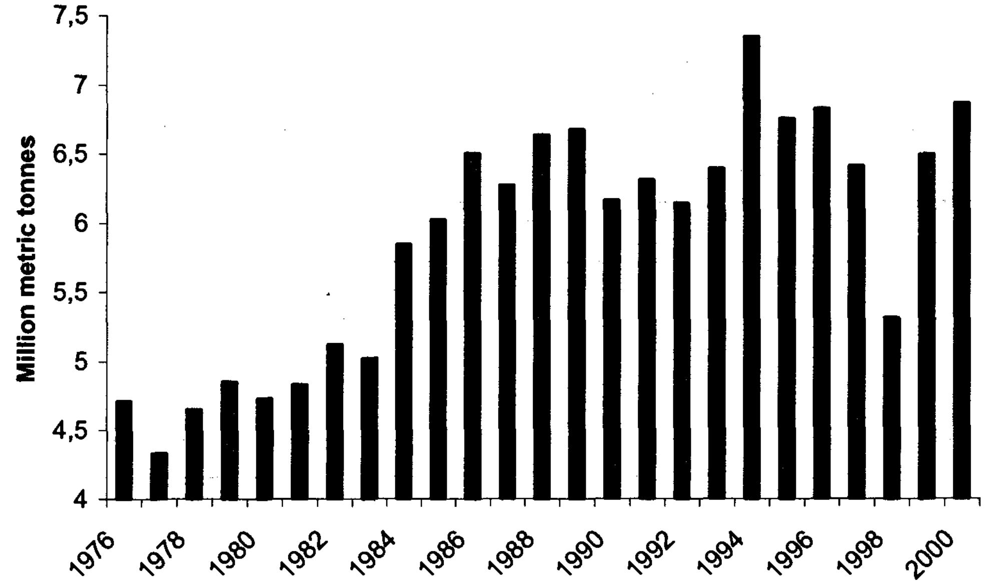

Figure 4. Global fish meal production from 1976 to 2000 (Source: FAO Fishstat, 2001)

Stagnating capture fisheries have left limited room to increase the supply of fish meal, and consequently the future price path of marine proteins depends on the development in fish meal consumption. Aquaculture is not the sole consumer of fish meal though, as the fish meal industry was well established before modern aquaculture started to expand. Marine proteins have been part of pig and poultry diets for several decades already, where it has shown beneficial growth effects on young animals relative to other protein sources. Like in aquaculture, livestock compound feed producers use least-cost formulas, which entails that one uses fish meal interchangeably with other protein sources like soybean meal, depending on what is the cheapest alternative. Substitution between fish meal and vegetable protein sources is reflected in the price movements of the various protein meals, by converging over time. In Figure 5 we can observe the close relationship between the fish meal and soybean meal price from January 1977 to June 2001, particularly before the 1990s. The price premium that fish meal commands over soybean meal arise from a higher protein content and a beneficial amino and fatty acid profile.

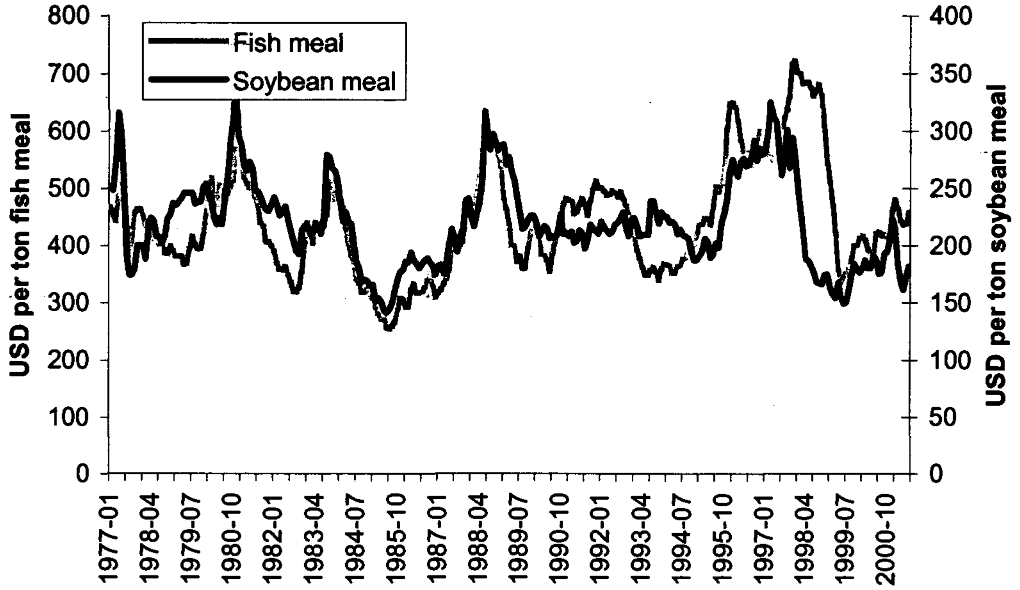

Figure 5. Monthly fishmeal and soybean meal price data from Hamburg and Rotterdam from Jan 1977 to Jun 2001 (Sources: OilWorld; FEO).

The future needs for marine proteins in livestock and aquaculture feeds will determine how the fish meal price will develop. Aquaculture's higher willingness to pay has already led to a displacement of poultry's consumption of fish meal, and producers of farmed marine species are now the largest consumers of fish meal. The fourth paper, "Fish Meal Demand from Livestock and Aquaculture", addresses the question of how much higher willingness to pay salmon aquaculture has relative to the pork and poultry sectors. It analyses empirically demand elasticities from the salmon and livestock production by estimating demand in countries with different relative sizes of aquaculture and livestock production. If demand from salmon farming is inelastic and remains that way, then limited availability of fish meal can effectively hinder further growth, not only for salmon production, but also for other intensively reared aquaculture species like cod, seabass, seabream, halibut etc. Such a scenario might not be realistic as technology will certainly change. However, the issue calls for attention since success in finding a new feed technology is not given.

2.3 Environmental Issues in Salmon Aquaculture

While the "fish meal trap" represents a resource constraint for the salmon aquaculture industry, others such as Naylor et al. (2000) view the use of marine resources in salmon feed as an unsustainable practice. They hold the view that aquaculture increases fishing pressure on wild fish stocks targeted for fish meal and fish oil, and can thereby lead to unsustainable fisheries. This issue is examined in the paper "On the Relationship between Aquaculture and Reduction Fisheries". The paper does not agree with the view that fish meal demand from salmon aquaculture is unsustainable, emphasising that sustainable fisheries is primarily a question of proper fisheries management. It has also been pointed out that some of the marine raw materials used in fish feeds should instead go directly to human consumption. Some of the fish species used for fish meal can undoubtedly be used as food fish, but that is somewhat besides the point. What seems to aggravate these opinion holders is that fish are diverted to the production of "luxury" goods in developed countries, instead of going directly to human consumption in poor countries. The issue is one of income distribution, not market failure (at least, if one accepts that fish products are allocated through markets). As it currently stands, fishing companies find it more profitable to allocate parts or all of their catches to fish meal and fish oil production than to alternative processing, e.g. canning for human consumption.

Despite the technological progress made in salmon farming several challanges remain. Environmentalists are concerned with externalities from intensive aquaculture activities to the local environment, with issues such as farmed salmon escapees affecting the genetic pool of wild salmon, spreading diseases and parasites to wild salmon.[11] Other worries relate to discharges of organic waste from fish farms, since the organic waste can have detrimental effects on the local marine environment. The adverse effects listed here relates to the intensive

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[11] Naylor et al. (2000)

nature of salmon farming. The farm sites introduce a high concentration of species unfamiliar in the local habitat, and as such can put strain local ecological systems. There is a reciprocity between fish farms and the local environment, as the internal productivity of salmon farms rely on a "healthy" local habitat. As such there is a motive to internalise some externalities, while others without negative feedback effects on productivity might not be addressed as actively. The final paper in the thesis address the environmental issues of salmon farming, particularly in view of the explosive growth of salmon farming industry. The study investigates whether industry growth leads to improved environmental practices, as it puts the industry in a more economical viable position to increase research and development efforts for environmentally friendly solutions. Such innovations can be induced by negative feedback of environmental problems on production or governmental regulations.

3 Theory and Method

3.1 Primary Goods Markets

As the title of the thesis suggests the focus is not only on markets for seafood products, but more generally on primary goods markets. Primary goods markets like fish, crude oil, natural gas, metals, grains, oilseeds etc. are all distinct with their own particular facets. Many of them do, however, share common characteristics. One of the most striking characteristics is the homogenous goods assumption, which is often applicable. The homogenous property of primary goods is partly because of the nature of the production process, with harvesting and minimal processing, and partly because of the end uses of primary goods. Consequently, the value of such goods usually reflects the cost of extracting or harvesting them, and to a lesser degree processing, leaving less room for product differentiation, unlike manufactured goods. For example harvesting fish or extracting oil implies that we gather 'the fruits of nature's own labour', without noteworthy altering the raw materials in the production process. Furthermore, primary goods are traded for further processing or incorporation into final goods, so that they only leave a smaller imprint on the end product. As world markets operate with international product standards designed to make trade easier and less risky, they also contribute to a homogenisation of primary goods.

When explaining price movements of primary goods one usually focuses on the supply side, particularly in the short run. The demand side receives correspondingly less attention. This may be understandable, as short-term price movements of commodities are often caused by volatile supply. Demand, on the other hand, tends to be more stable in the short run. The volatility relate to harvest and extraction of natural resources, where particularly the harvest of renewable resources tend to be associated with uncertainty. To understand long-term development in primary goods prices it is, however, essential to include the demand side in the analysis. This approach is followed here with the panel data analysis of fish meal demand in the fifth paper, "Fish Meal Demand from Aquaculture and Livestock: Inference Using a Shrinkage Estimator for Panel Data". The demand side in primary goods market is often composite due to the multiple uses of primary goods, as opposed to manufactured goods. With the different uses typical of primary goods, and shifts in the use can lead to changes the value basis of the product. For example aquaculture's increasing fish meal consumption is displacing other uses of fish meal, can lead to an increasing valuation of fish meal.

3.2 Product Aggregation and Market Integration

This leads us to a discussion concerning what information prices contain, when investigation primary goods markets. First of all the homogenous goods assumption is a generalisation; an abstraction so to speak, and a description one should be careful in applying to specific products and markets without further investigation. So how do we go about examining whether goods are homogenous or not? The question falls into a core topic in applied economics, namely that of aggregation, and in this case, aggregation over goods. There are several approaches to the aggregation issue in applied economics depending what is the focus of the study and what are available data. Since the main focus here is on markets, prices are our most important source of information. In "Aggregation over different qualities: Are there generic commodities?“ we present a method for aggregation products using only prices, based on Lewbel's generalised composite commodity theorem (1996). The idea is that when the prices of two or more products follow each other over time, forming a linear relationship that is stationary, then the products can be treated as one and represented by a common price index.

Asche, Bremnes, and Wessels (1999) noted there is a close relationship between generalised composite commodity theorem and the 'law of one price'. Although one is concerned with product space and the other with geographical space, they both purport the same relationship between prices. Even the name, 'law of one price', signal their relationship as it points to the common price index of the generalised composite commodity theorem. Stigler (1969) defines the extent of the market as "the area within which the price of a good tends to uniformity, allowance being made for transportation costs". The 'law of one price' thus describes a tightly integrated market, whereby the price in one location maps the price in another location 1:1 after accounting for transaction costs.

So how close do the prices have to follow each other before they represent an integrated or a well-integrated market? McCloskey (1998) put forward this question pointing to the fact that it is not trivial whether e.g. prices are correlated with a factor of e.g. 0.85, 0.95 or 1. The question is "how large is large?" and what constitutes a market, where McCloskey draw a parallel to linguistics:

> "The point is that linguists face the same puzzle that economists face: How large is large? How large do the differences between dialects of Dano-Norwegian have to be before you count Danish and Norwegian as separate languages? You can watch the linguists missing the point just as economists do. The linguists sometimes use "mutual intelligibility" as a standard for defining a language, but like the correlation of prices, it immediately demands a higher-order standard. If you say that a correlation of +.80 between prices of grain in Glasgow and London is "high" you are assuming a rhetorical context that provides a scale along which the number is in fact high." (McCloskey 1998, pp. 104-105)

The point here is that economists can draw different conclusions of what story prices tell, even when they face the same data. The second and third paper are both on market integration. The two studies implicitly use a metric for market integration, which although not new seems sensible: a market is integrated between two locations when prices in the two locations are cointegrated. When one has two price series integrated of 1. order, I(1), cointegration entails that the prices converge in the long run. This conforms to what one would expect in an integrated market. Further, a market is *well*-integrated when the 'law of one price' hypothesis is not rejected. With 'the law of one price' prices not only converge, but the relative prices are constant in the long run. There is still room for arbitrage in the short run, but in an imperfect world this might be viewed as reasonable. Herein probably lies part of the explanation why some studies have such a large rejection rate of the 'law of one price'. This includes Richardson's "Some Empirical Evidence of Commodity Arbitrage and the Law of One Price" (1978), which our "Market Integration and Exchange Rates in Commodity Markets" is indebted to. In his study the 'law of one price' tests fail uniformly between different groups commodities between USA and Canada.

A 'law of one price' test does not tell the whole story, though, and one needs to consider what prices represent in three dimensions; time, geography, and product space. For example are prices reported in the beginning or the end of a period? We can also question whether actual trade takes place between two market locations that we test for market integration. In a setting where there is Bertrand competition such test can be meaningful, while in other settings it would be doubtful. Yet, with the framework used here one should be able to dismiss such cases by rejecting market integration. Two unrelated, or only weakly related, nonstationary prices are unlikely to be cointegrated. Richardson (1978) is however interesting because he includes exchange rates in his market integration framework. Inclusion of exchange rates opens up for additional information on market structures. This line is followed up in "Market Integration and Exchange Rates in Commodity Markets" by combining Richardson's framework with the Johansen multivariate cointegration procedure (1988, 1991). By using the Johansen test one can test for exogeneity, and as such use exchange rate in price discovery.

3.3 Heterogeneity versus Homogeneity

The fourth and fifth papers in the thesis are both concerned with heterogeneity, one along time and the other across individuals. It has become increasingly widespread in econometric modelling to include heterogeneity. It is one of those phenomenons which many economists have taken to their hearts, realising that describing a world inhabited with identical agents, can be misleading at the least. However, as economists know, tradeoffs are part of the day, and the question is what is the price of including heterogeneity in econometric models? It does lead to less degrees of freedom, as heterogeneity means more parameters to estimate. Another question is how well one captures the real-life heterogeneity one studies. ”Forecasting with Two Price Regimes: A Markov-Switching VAR Model for Fish Meal Price” and ”Modeling Demand for Fishmeal Using a Heterogeneous Estimator for Panel Data” consider potential tradeoffs of including heterogeneity, the first in terms of forecasting and the other in terms of inference. One of the main purposes of econometric models is to highlight certain aspects of reality. In this respect it is not certain that opening up for heterogeneity is purposeful, even if in some respects it leads to a more “true” model, to the extent that it is meaningful to talk about true models. The main focus of the papers is, however, on useful economic information contained in heterogeneous models.

4 Empirical Findings and Policy Implications

The main focus of this thesis is the value chain for salmon aquaculture, with particular attention to the scarcity issue of fish meal. Four studies cover the fish meal market, highlighting several aspects relating to the fish meal scarcity issue. The study “On the Relationship Between Aquaculture and Reduction Fisheries” finds a strong relationship between the fish meal market and the soybean meal market. With the restricted cointegration test, the ‘law of one price’ is not rejected, which implies that the relative prices between fish meal and soybean meal are constant in the long run. On its own, such a result dismisses the scarcity issue, since the strong market integration entail that soybean meal and fish meal are perfect substitutes. There are other circumstances that need to be considered though. The relationship between these prices reflects that marine and vegetable protein inputs are used interchangeably, but the cointegration test does not capture the changing consumption pattern of fish meal.

The 1998 El Niño, with the high fish meal prices, acted like a catalyst in changing the consumption of fish meal. With aquaculture's higher willingness to pay for marine proteins, it has displaced part of the use livestock feeds. In "Fish Meal Demand from Aquaculture and Livestock: Inference Using a Shrinkage Estimator for Panel Data" the differences in willingness to pay is quantified in the shape of fish meal demand elasticities for salmon aquaculture and jointly for pig and poultry. There is a separability problem with properly identifying the two sectors' demand, which entails that the results have to be interpreted with some care. Still, the panel data model for fish meal demand gives some fairly uniform results. Countries with considerable salmon production have consistently lower own-price elastic demand than countries that mainly demand fish meal for pig and poultry production. With an own-price elasticity around 0.2 for salmon producing countries, the shrinkage estimator suggests that demand is close to being completely inelastic. There are reasons to suspect this result is somewhat downward biased. In any case, the relatively more inelastic demand of aquaculture compared with that of livestock implies that aquaculture growth will continue displacing livestock. The inelastic demand also implies that prices will increase unless new feed technology changes aquaculture's needs for marine proteins.

The Markov switching model for the fish meal price supports this view. With two price regimes for fish meal, the model suggests there is one regime where the fish meal price is integrated with the soybean meal price and another where the two markets disconnect. One can think of the regime changes as an expression of changing market expectations. When the market perceives supply is getting tight then the fish meal price disconnects from the soybean meal price. This reflects a kinked demand curve, and following the results from the demand model, the inelastic segment is primarily represented by the aquaculture sector. More plainly, when compound fish feed producers observe that fish meal supply is getting tighter they pay more to secure their own needs for marine proteins.

The picture laid out here is one of a beginning scarcity for fish meal. The manifestations are the increasing displacement of fish meal from livestock feeds and the more frequent disconnections between the fish meal and soybean meal price. Both trends have begun with the 1990s, following the expansion of the aquaculture industry. For the fish meal industry the scarcity of fish meal will translate into higher prices and possibly higher profit margins. The implications in the long run are more uncertain though. It is not certain that increasing prices of marine proteins is in the fish meal industry's interest. Higher prices can induce aquaculture and other fish meal consumers to look harder for alternatives, making scarcity a short-lived affair.

For salmon farmers the prospect of rising fish meal prices is not tempting either. Being dependent on raw materials associated with a volatile supply leaves much to be desired. This situation can make salmon aquaculture producers let go of its former high-price status. The expansion of salmon aquaculture has been made possible by falling production costs. A logical next step, which now seems to be emerging, is to create a 'vegetable' salmon, freeing itself from the constraints of using marine raw materials.

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PAPER 1

Aggregation over different qualities:

Are there generic commodities?

by

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and

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Abstract

Aggregation over goods is always an issue in empirical analysis. However, while the problem of aggregation over different goods often is analysed, little attention has been given to the properties of generic goods such as e.g. coffee, wheat and salmon. Often these generic commodities contain a number of different qualities. In this paper a test for aggregation based on Lewbel's Generalized Composite Commodity Theorem (GCCT) using only price data is used to validate aggregation. We show by using price series for different weight-classes of salmon that the generic term salmon can be used for these products.

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1. Introduction

Aggregation over products is always an issue in empirical economic analysis. This is partly because data are recorded in generic categories like wheat, coffee etc., and partly to give empirical models manageable proportions. It is well known that if goods are aggregated inappropriately, this may introduce serious biases in empirical analysis and cast doubt on the validity of the results (see e.g. Deaton and Muellbauer, 1980 and Lewbel, 1996). However, a recurrent problem is how to validate aggregation over goods for use in empirical estimations. While aggregation issues have been investigated in a number of studies, we are not aware that the appropriateness of generic categories like salmon, tomatoes or tea has been investigated. However, even for most generic categories of this type, there are different quality grades, which may lead goods in the same generic group to form different markets.

There are two fundamentally different approaches to validate aggregation – different forms of separability and relationships between prices (Deaton and Muellbauer, 1980). Relationships between prices have been operationalized for empirical analyses by Lewbel (1996) in his generalized composite commodity theorem (GCCT). Moreover, Asche, Bremnes and Wessells (1999) show that one can obtain information on aggregation from only price data. In this paper we will test for aggregation using only price data, which tend to be the easiest available form of data to investigate this issue. We will here utilize this approach to investigate whether different sizes of salmon can be aggregated into the generic group salmon.

2. The composite commodity theorem

The composite commodity theorem (CCT) of Hicks (1936) and Leontief (1936) provides a condition that is consistent with utility maximization for the relationships between prices under which it possible to represent the group of goods with a single price and quantity index. Following Deaton and Muellbauer (1980), the CCT holds for two goods when

(1) $P_{1t} = \theta_t P_{10}$ and $P_{2t} = \theta_t P_{20}$,

Since it is the common trend given by θ_t that determines all values of both prices, this implies that the CCT holds when prices are proportional. This relationship holds for any number of good as long as all prices from a base period is determined by the common trend θ_t, which is a representation of the groups price index. The relationship that θ_t describes between the prices is strictly deterministic. It is evident that finding such relationship between prices in empirical analysis is near impossible. Real life prices do not exhibit deterministic relationships no matter if they are close substitutes since there always will be some kind of noise influencing the fluctuations. Unfortunately, these arbitrary errors are nontrivial when it comes to aggregation (Lewbel, 1996).

However, Lewbel provides a generalization of the CCP that is empirically useful, the GCCT. Define ρ_i as the ratio of the price of good i to the price index of group I.

(2) $\rho_i = \log(p_i / P_I)$

Here, ρ_i is the ratio of the price of good i to the price index of group I. Let $r_i = \ln p_i$ and $R_I = \ln P_I$. Thus, we can the define the relative price according to Lewbel as

(3) $\rho_i = \ln(p_i / P_I) = r_i - R_I$

Lewbel shows that for nonstationary prices the criteria for aggregation is that the price ratio ρ_i has to be independent of the group index P_I. This will be true if the prices are nonstationary and u_t in equation (3) is stationary, since ρ_i and the group index I then are I(0) and I(1) respectively. This is equivalent to stating that the relative price ρ_i is not cointegrated with P_I.

A problem often encountered is that only price data is available in testing for aggregation. The GCCT requires the use of a group index, but the construction of these indexes need both price and quantity data, i.e. like the Paasche index or Laspeyres index. However, as noted by Asche, Bremnes and Wessells (1999), since θ_t can be regarded as the price index for the group, this will be nonstationary when the prices are nonstationary. If the prices are proportional with the exception of a stationary deviation, the relative price ρ_i will be stationary. Moreover, any of the prices will be a scaled representation of θ_t, because this is the stochastic trend. Since the order of integration then is different from the group index, the relative price and the price index cannot be cointegrated and the GCCT holds. However, although one can confirm that aggregation is valid with this procedure, one cannot reject the GCCT, since the relative price ρ_i can be nonstationary and the GCCT may still hold. However, then one needs a different price index for the group.

Asche, Bremnes and Wessells (1999) use their results to argue that the Law of One Price is sufficient for the GCCT to hold. However, their results also indicate that one can investigate whether the GCCT holds by investigating whether the ratio of nonstationary prices are stationary by running Dickey-Fuller tests. When testing for cointegration using Dickey-Fuller tests, a constant term should be included either in the cointegrating relation or in test for stationarity of the residuals (MacKinnon, 1991). Since we are imposing proportionality in the cointegration relationship, when constructing the relative price a constant term must be included in the Dickey-Fuller test. The test for the GCCT using only prices is then performed by testing whether the relative price ρ_i is stationary given that the prices are I(1).

Figure 1. Atlantic salmon price for 4-5 kg weight class from August 1991 to January 2001 (Norwegian Seafood Producers Association, NSL)

3. Empirical Results

We will here illustrate how these tests can be used to confirm that a generic name can be used for a product with potential quality differences. The good used in the empirical analysis is salmon, for which weight is an important quality characteristic. We have Norwegian producer prices Atlantic salmon for six different weight classes; 1-2 kg, 2-3 kg, 3-4 kg, 4-5 kg, 5-6 kg and finally 6-7 kg.[12] The prices are recorded on a monthly basis from August 1991 to January 2001. The price series of 4-5 kg is shown in Figure 1 and descriptive statistics are reported in Table 1.[13] We see that the higher weight classes of salmon receive higher prices per kilo than the lower weight classes. However, they also experience larger variations in their prices. From Table 2 we can see that there is a high degree of correlation between the price series, indicating that these prices are closely related. The correlation decrease the farther part the weight classes are from each other. Still, prices of 1-2 kg salmon and 6-7 kg salmon are correlated with a coefficient of 0.75, which is relatively high.

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[12] The prices are provided by the Norwegian Seafood Producers Association (NSL).

[13] This is the price used as a proxy group index for the generic group salmon in the empirical tests.

Table 1. Descriptive statistics of salmon price data

	Means	*Standard deviations*
$\ln p_{1\text{-}2\,\mathrm{kg}}$	27.74	5.0421
$\ln p_{2\text{-}3\,\mathrm{kg}}$	27.97	5.7556
$\ln p_{3\text{-}4\,\mathrm{kg}}$	29.40	6.5804
$\ln p_{4\text{-}5\,\mathrm{kg}}$	30.17	6.9259
$\ln p_{5\text{-}6\,\mathrm{kg}}$	30.38	7.0912
$\ln p_{6\text{-}7\,\mathrm{kg}}$	30.60	7.3086

Table 2. Correlation matrix of salmon prices

	$\ln p_{1\text{-}2\,\mathrm{kg}}$	$\ln p_{2\text{-}3\,\mathrm{kg}}$	$\ln p_{3\text{-}4\,\mathrm{kg}}$	$\ln p_{4\text{-}5\,\mathrm{kg}}$	$\ln p_{5\text{-}6\,\mathrm{kg}}$	$\ln p_{6\text{-}7\,\mathrm{kg}}$
$\ln p_{1\text{-}2\,\mathrm{kg}}$	1.0000					
$\ln p_{2\text{-}3\,\mathrm{kg}}$	0.9594	1.0000				
$\ln p_{3\text{-}4\,\mathrm{kg}}$	0.8629	0.9428	1.0000			
$\ln p_{4\text{-}5\,\mathrm{kg}}$	0.7933	0.8983	0.9768	1.0000		
$\ln p_{5\text{-}6\,\mathrm{kg}}$	0.7508	0.8576	0.9442	0.9831	1.0000	
$\ln p_{6\text{-}7\,\mathrm{kg}}$	0.7500	0.8504	0.9095	0.9487	0.9820	1.0000

We continue by investigating the time-series properties of the variables, using (augmented) Dickey Fuller tests. The results from the tests are reported in Table 3 with the number of lags in parenthesis. The null hypothesis of at least one unit root cannot be rejected for any of the price series. Furthermore, all the first differences of the price variables reject then null of unit root. Thus, we can conclude that all the prices are nonstationary I(1) processes.[14] The next step is to test if the ρ_i's are stationary. We normalize by the price of 4-5 kg salmon, as this is the largest group. In Table 4 the Dickey-Fuller tests for ρ_i's are reported, and in all cases the null hypothesis of nonstationarity is rejected. Hence, we can conclude that the GCCT holds for different weight classes of salmon. This implies that it is valid to use the generic term salmon.

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[14] This is as expected since a number of studies have concluded that salmon prices are $I(1)$. See e.g. Gordon, Salvanes and Atkins (1993), Asche (1996) and Asche, Bremnes and Wessells (1999).

Table 3. Augmented Dickey Fuller tests for unit roots of salmon prices. Monthly observations from Aug 1991 to Jan 2000

Salmon price variables	ADF statistics	
$r_{1\text{-}2\text{ kg}}$	-2.0289	(4)
$r_{2\text{-}4\text{ kg}}$	-2.0181	(4)
$r_{3\text{-}4\text{ kg}}$	-2.3396	(4)
$r_{4\text{-}5\text{ kg}}$	-2.5255	(4)
$r_{5\text{-}6\text{ kg}}$	-2.6707	(4)
$r_{6\text{-}7\text{ kg}}$	-2.7472	(4)
$\Delta r_{1\text{-}2\text{ kg}}$	-5.2217**	(4)
$\Delta r_{2\text{-}4\text{ kg}}$	-5.6255**	(4)
$\Delta r_{3\text{-}4\text{ kg}}$	-6.4949**	(4)
$\Delta r_{4\text{-}5\text{ kg}}$	-6.8750**	(4)
$\Delta r_{5\text{-}6\text{ kg}}$	-6.5553**	(4)
$\Delta r_{6\text{-}7\text{ kg}}$	-6.7269**	(4)

Critical values: 5%=-2.892, 1%=-3.499 respectively denoted as * and **. Number of lags used in ADF test in parentheses.

Table 4. Augmented Dickey Fuller tests for unit roots of the log of the ratio, ρ_i. 4-5 kg price functions as proxy for the group price index R_I. Monthly observations from Aug 1991 to Jan 2000

$\rho_i = r_i - R_I$	ADF test statistics	
$r_{1\text{-}2\text{ kg}} - R_I$	-4.7283**	(6)
$r_{2\text{-}4\text{ kg}} - R_I$	-5.4653**	(6)
$r_{3\text{-}4\text{ kg}} - R_I$	-5.5012**	(6)
$r_{5\text{-}6\text{ kg}} - R_I$	-5.7751**	(6)
$r_{6\text{-}7\text{ kg}} - R_I$	-5.7369**	(6)

4. Concluding remarks

Generic commodity names like e.g. salmon, coffee or wheat often includes a number of qualities, and one can in many cases question whether it is valid to treat them as one aggregate commodity. The Generalized Composite Commodity Theorem of Lewbel (1996) can be used to confirm that this aggregation is indeed valid using only data one prices. An empirical investigation of prices for different weight classes of salmon indicates that it indeed is valid to aggregate them into the generic category salmon.

Acknowledgements

Financial support from the European Commission (QLT5-CT 1999-01346) and the Norwegian Research Council is acknowledged. The views expressed herein are the authors', and not those of these organizations.

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PAPER 2

On the relationship between aquaculture and reduction fisheries

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Thanks to Rögnvaldur Hannesson, Jim Sanchirico and Stein Ivar Steinshamn for helpful comments. Any mistakes, however, are the responsibility of the authors.

On the relationship between aquaculture and reduction fisheries

Abstract

Traditional aquaculture has to a large extent used herbivore species with limited requirements for additional feeding. However, in intensive aquaculture production one farm carnivore species like salmon and also feeds herbivore species with fishmeal as this increase growth. This has lead to a growing concern that increased aquaculture production poses an environmental threat to the species targeted in reduction fisheries as increased demand increase fishing pressure. In this paper we address this question along two lines. First, under which management regimes may increased demand pose a threat to the species in question. Second, we investigate what is the market for fishmeal. Is fishmeal a unique product or is it a part of the larger market for oilmeals which includes soyameal? This is an important issue since the market structure for fishmeal is instrumental for whether increased aquaculture production may affect fishmeal prices, and thereby increase fishing pressure in industrial fisheries.

1. Introduction

During the last decades there has been a substantial increase in aquaculture production. The major cause for this development is new farming techniques allowing intensive aquaculture production.[16] This has led to a number of environmental concerns. These concerns can be divided into two main groups. The first group is pollution of the local and regional environment due to discharges from the production process, and in some cases destruction of habitat. These concerns tend to be local problems and can, at least in principle be solved by local regulation (Asche, Guttormsen and Tveterås, 1999).[17] The second concern is that growing aquaculture production leads to an increased fishing pressure on wild stocks due to increased demand for fishmeal, as fishmeal is an important part of the diet for cultured seafood (Naylor et al., 1998). This is an interesting observation, since it implies that the aquaculture industry creates environmental problems via the markets for its inputs. Moreover, since the market for fishmeal is global, this is then a global problem. This issue is also of interest because if it is a serious problem, it puts clear limits on how large aquaculture production can be.

In this paper we will focus on the impact of aquaculture on wild stocks through the demand for fishmeal. The analysis will be carried out in two parts. First, we will discuss how increased demand will affect landings and therefore fish stocks in a simple bioeconomic model. The effects of increased demand will be dependent on the management structure, and there are a number of management forms in the world's fisheries. However, these can be divided into three main groups; open access, sole-owner (or optimal management), and restricted open access. We will therefore analyze the effect of increased demand with three

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[16] Traditional or extensive aquaculture differs from intensive or industrial aquaculture in scale and production technology. In particular, in extensive aquaculture the fish is not fed, but consumes whatever nature provides at the location.

[17] Several of these potential negative externalities will also be internalized by the farmers, as they also affect their productivity (Asche, Guttormsen and Tveterås, 1999).

benchmarks based on these groups, where we use TAC (Total Allowable Catch) regulation as a representative restricted access fishery.[18]

Second, to what extent an increased demand for fishmeal will lead to increased demand for fish, will also depend on what is the market and uses for fishmeal. Fishmeal is not the only possible feed in aquaculture production and it is not used as feed only in aquaculture production, but also in agriculture.[19] Most cultured species can use at least some vegetable meals such as soyameal in their diet, and quite a few cultured species like carp, tilapia and American catfish is herbivore in nature. However, fishmeal is increasingly used in their diet to increase growth. Moreover, most fishmeal is currently used in agriculture as feed in poultry, pork and livestock production. It is therefore of substantial interest whether fishmeal is a unique product on its own or a part of the oilmeal market and a close substitute for e.g. soyameal. This is because the market structure is instrumental in determining how increased demand for feed from aquaculture producers can affect the price determination process for fishmeal.

2. Increased Demand and Fisheries Management

In this section we will first give a brief overview of the world's industrial fisheries. We will then turn to a simple bioeconomic model to illustrate the importance of management regime when demand increases, before we discuss the state of the most important industrial fisheries in this light.

2.1 Industrial fisheries

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[18] Other regulations that can be used in regulated open access fisheries include input controls and taxes.

[19] A small part is also used for human consumption.

The world's reduction fisheries are mainly based on fisheries for small pelagic species.[20] Pelagic fish are used both for human consumption and for reduction, i.e. fishmeal and fish oil, but certain species are only fit for reduction due to their consistency, often being small, bony, and oily.

Normal yearly catches in the 1990s with the main purpose of reduction to fishmeal amount to approximately 30 million MT (metric tons), giving an average of 6-7 million MT fishmeal. The main fishing nations in 1997, when the fishmeal production was 6.2 tonnes, are shown in Figure 1. Chile and Peru alone deliver over 50% of the global fishmeal production based on their rich fisheries of Peruvian anchoveta, Chilean jack mackerel, and South American pilchard. Other substantial producers are the Nordic countries Denmark, Iceland and Norway. Combined their fisheries produce 15% of the global fishmeal production.

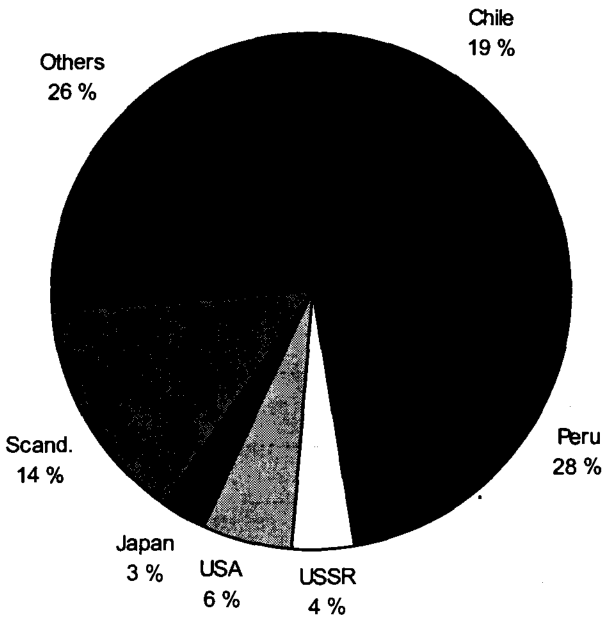

Figure 1. World fishmeal production in 1997 (Source: FEO)

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[20] Pelagic fish are free migrating fish species that inhabit the surface waters, as opposed to demersal fish that inhabits the sea floor.

A characteristic of the pelagic fisheries is that the quantity going directly to human consumption stays relative stable, while the "surplus" that goes to reduction can vary quite dramatically (Hempel, 1999). Thus, in years when the catches are low, such as *El Niño* periods, the fishmeal industry is hard struck. Also, the pelagic fisheries have generally been described as fully exploited or over-exploited by the FAO (Grainger and Garcia, 1996). Hence, a significant expansion of the global fishmeal production, beyond the 6-7 million MT that is normally produced, is not very likely.

2.2 A simple bioeconomic model

Let us then turn to the effect of increased demand in a fishery. We will only use the basic Gordon-Schaefer model, since introducing dynamics will not add essentially to our discussion of why increased demand for a species might be a threat against the species. If the fishery is regulated by a sole-owner, this agent will then have a zero discount rate in this simple form of the model. Textbook versions of this model cover the two most common institutional configurations in the fisheries economics literature in its simplest form, open access and optimal management (Homans and Wilen, 1997).[21] In addition to these two institutional configurations, we will also consider a regulated open access setting, since this is the most commonly observed management structure in the world's fisheries. We will here use a TAC as an example of the kind of a regulated open access fishery, but also other regulations like input factor restrictions or taxes can be used in place of or together with TACs. In this management setting one or more input factors are regulated, so that the fishery is generally regarded as biologically safe. However, one pays little attention to the economics of the fishery, and one typically observes over-capacity and rent dissipation. For simplicity we do not let the regulator be an endogenous part of the model as in Homans and Wilen (1997), but

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[21] Good representations of this model can be found a number of places, e.g. Anderson (1986), Hannesson, (1993) or Munro and Scott (1985).

let the quota be set exogenously. This is probably not a very severe assumption since biological considerations tend to dominate economic issues when quotas are set.[22]

The net natural growth in the biomass is

(1) $F(x) = rx(1 - x/k)$.

where x is the biomass, r is the intrinsic growth rate and k is environmental carrying capacity. This function also gives the sustainable yield for different levels of the biomass. The value of the sustainable yield can be found by multiplying (1) with a price p, giving the sustainable revenue curve, TR. We will here, as in most analysis assume that the price is given from a world market, as certainly is reasonable for species that are used for fishmeal production. Harvest H is given as

(2) $H = \gamma x^{\alpha} E$

where γ is a catchability coefficient, α gives the strength of the stock effect and E is fishing effort. The fishery is in equilibrium when $F(x)=H$. Fishing cost is

(3) $C = cE = cH / \gamma x^{\alpha}$

where c is the unit cost of fishing effort. Total profits or rent are

(4) $\Pi = pH - cE$

This model has two equilibria: Under open access all rents are dissipated, and the biomass is at the level x^{∞}. Under rent maximization the biomass is at the level x^{0}. This is graphed in Figure 2, where the sustaninable revenue curve, TR, is shown together with the cost curve, C. As one can see, $x^{\infty}<x^{0}$, and one can also show that effort in an open access fishery is higher than in an optimally managed fishery, i.e. $E^{\infty}>E^{0}$. Under regulated open access, total harvest is

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[22] It may be worthwhile to note that also Individual Transferable Quota (ITQ) schemes can be regarded as restricted open access. The main difference between ITQ's and other restricted access schemes is that the fishermen's incentives are changed from maximizing their share of the catch to maximize profits for their share of the catch.

determined by a quota Q. This is typically determined mainly by biological considerations. This will then lead to a biomass at some target level, x^Q, which under our assumptions are set without any economic considerations.

Assume then that the price increases due to increased demand at the world market. This will lead to an increase in the value of the natural growth of the fish stock and the harvest. This is introduced in the Figure 3 with the new sustainable revenue schedule, TR'. In the cases when the fishery is in open access or regulated by a sole owner, the increased value of the fish will lead to an increase in effort and to a decrease in the biomass. Under open access, for most stocks this will also lead us further up on the backward-bending part of the supply schedule. Lower landings will then give even higher prices and put further pressure on the stocks. At some point cost will prevent more effort, but in many fisheries this might be at very low levels of biomass. In particular, pelagic stocks with weak stock effects (i.e. an α parameter close to zero) can be driven down to very low levels.[23] This is important here, since many of the stocks targeted in reduction fisheries are pelagic. In the case with optimal management, landings will respond to the increased prices. However, the biomass will always be higher than $k/2$, or the biomass associated with Maximal Sustainable Yield (MSY), which traditionally has been the management criterion advocated by biologists. One can then hardly argue that the fishery poses a threat to the stock.[24] If the fishery is regulated by a quota that is set without paying attention to economic factors, the quota remains the same, the biomass remains the same, but the value of the catch increases. Hence, we have the obvious conclusion that if the fishery is not allowed to respond to economic incentives, increased prices due to increased demand will not have any effect. Accordingly, the real problem is in the open

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[23] See e.g. Bjørndal (1987; 1998) for a discussion of such fisheries.

[24] However, when dynamics and a positive discount rate is introduced, one can show that for stocks with very low growth rates it may be economically optimal to drive the stocks to very low levels or extinction (Clark, 1973).

access scenario, since increased demand for a species in this scenario might lead to serious depletion of the stock, and will increase the risk of extinction. The model outlined here allows the stock to be driven down to very low levels, although not to become extinct. However, it is clear that with very low stock levels the species also becomes substantially more vulnerable to changes in other factor like water temperature, salinity, etc. that are not accounted for in the model. In more general models, one may also increase the probability for extinction.

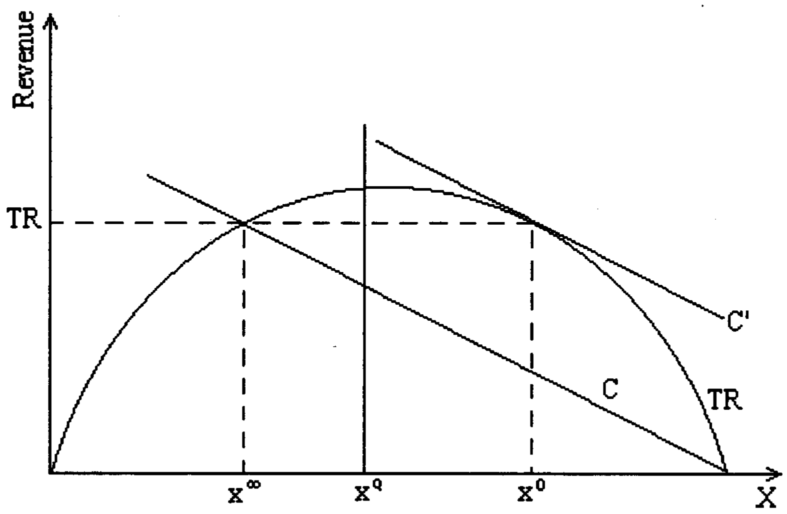

Figure 2. Revenue and fishery stock in three regulation schemes

2.3 *The management of industrial fisheries*

The analysis above indicates that increased demand for any species will mainly be a problem if the fishery is not managed, i.e. is operated as an open access fishery. How is then the management situation for the most important stocks used in industrial fisheries? Most of the world's fisheries for reduction are carried out in relatively few countries, with Peru and Chile as the most important (see Figure 3). The stocks of Peruvian anchoveta and Chilean jack mackerel have shown their vulnerability both due to the weather phenomenon *El Niño* and poor fisheries management. However, the fisheries management has improved over the last decade, with increasingly stricter regulations on inputs.[25] The most important tools used in Chile and Peru today are limiting access, quotas, input factor regulations and closures that are imposed on the fisheries in certain periods and certain areas. The industrial fisheries in the Nordic countries are regulated by TACs, and often additional restrictions. Due to different national interests these TACs often exceed biologically based advice. However, the overall state of the fisheries for reduction in the Nordic countries has improved substantially after herring stock collapses in the late 1960s and early 1970s, and several of these stocks have been rebuilt to the levels before the collapses. In the US, the menhaden fishery is the main industrial fishery, and also here the fishery is regulated with a TAC.

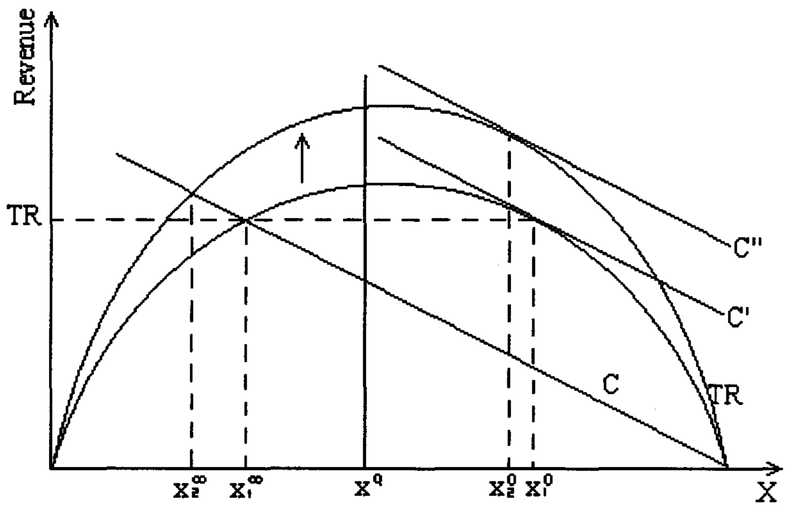

Figure 3. Changes in revenue and fishery stock induced by an increase in price for industrial fish

A first glance may indicate that the management situations for the most important pelagic fisheries are not too bad, and that open access is not a correct description. However, quotas tend to be high and one may often question whether the state of the fish stocks has the main priority when the quotas are set. Hence, it is not clear that the situation is very different from what it would be under open access. Many of these fisheries might as such be good examples

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[25] For a discussion of fisheries management in Chile, see Peña-Torres (1997).

of Homans and Wilen's (1997) notion that management is an endogenous part of the fishery.[26] Whether increased demand for fishmeal from a growing aquaculture industry is harmful for the state of the fish stocks that are targeted in industrial fisheries will then to a large extent depend on the market structure for fishmeal.

3. The market

We will now turn to the market for fishmeal. What is the market is an important question since this to a large extent will determine whether increased demand from aquaculture will affect prices with poor management of the stocks. In this section we will first provide a brief discussion of the world's oil meal markets and our data. We will then outline the methodology we use to delineate the market before we discuss the empirical results.

3.1 The world's oilmeal markets and data

There is little doubt that the markets for fishmeal are global. In fact, this is a main part of the criticism against the aquaculture industry, as it is the prime example that negative environmental effects are global and not only local. However, the aquaculture industry is far from the only user of fishmeal. In Figure 4, the main sectors that use fishmeal are shown for 1997. As one can see, aquaculture is relatively small, using about 17% of the production. Moreover, for most of the species that use fishmeal as feed, this is only a part of their diet. Other oilmeals, with soyameal as the largest also make up a major share. If one look at the total market for oilmeals, global fishmeal production is rather minor compared to the total oilmeal production, as shown in Figure 5.

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[26] It might be of interest to note that the open access equilibrium is also the equilibrium with the highest level of effort. Hence, if one is to maximize e.g. employment in a fishery, one is likely to end up very close to the open access equilibrium. Other objectives than rent maximization can therefore lead to substantially higher quotas and lower biomass. Moreover, regional policy and employment are often important parts of fisheries policy, and therefore management.

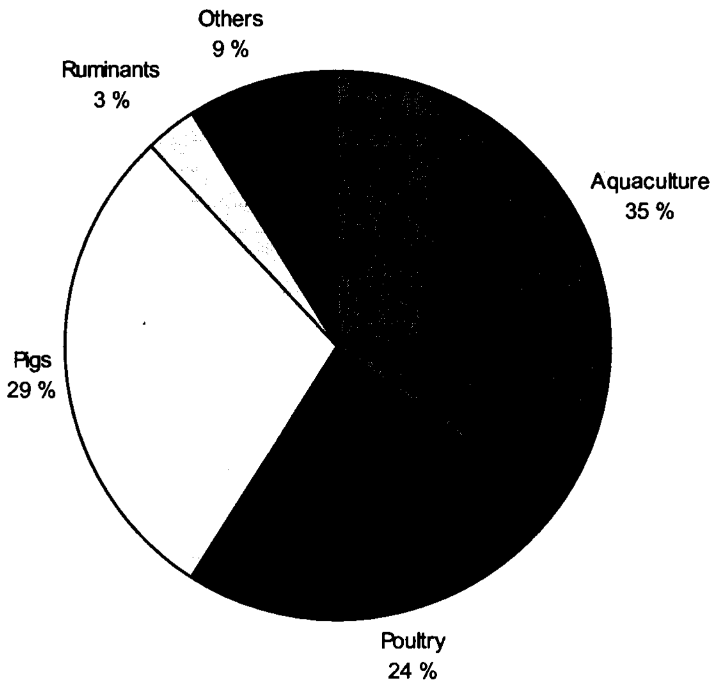

Figure 4. Estimated total use of fishmeal (Source: Pike, 2000)

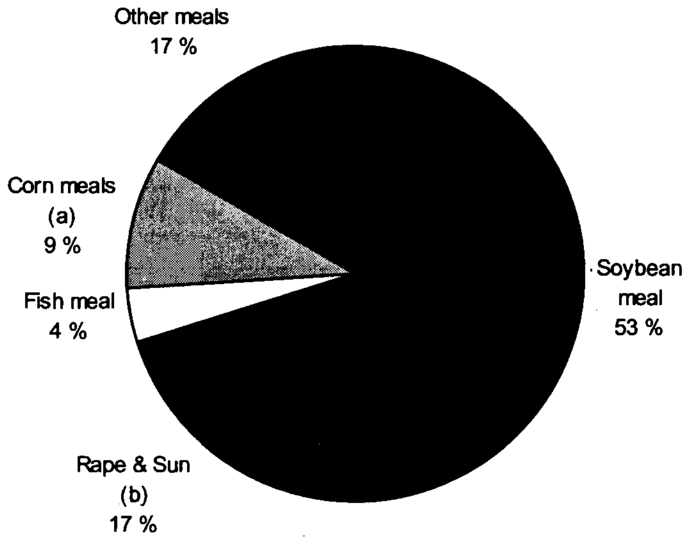

Figure 5. World production of oilmeals 1996/97 (Source: OW, 1999)
(a) Corngerm & cornglutenfeed. (b) Rapeseed meal & sunflower seed meal

There are two main explanations why fishmeal is used in livestock production. One explanation stresses the uniqueness of fishmeal. Fishmeal has higher protein content than the other oilmeals, and also has a different nutritional structure. In particular, this is the case with respect to amino acids that may be positive for the general health of the animals. The other explanation emphasizes that fishmeal in general is cheap protein. These two explanations have very different implications for the price formation process for fishmeal. If fishmeal is used because it is unique, the price of fishmeal should be determined by the demand and supply for fishmeal alone. One the other hand, if fishmeal is used mainly because it is cheap protein, one would expect a high degree of substitutability between fishmeal and other oilmeals.[27] If the first explanation is correct, increased demand from aquaculture production for fishmeal are likely to increase prices, and therefore increase fishing pressure after poorly managed fish stocks. This might be true even if aquaculture's share of the demand is a low as 17%, since the additional demand from aquaculture then has to be met partly by aquaculture taking over fishmeal from other producers that find it too expensive and partly because the higher price increases production. However, if fishmeal is a close substitute for other oilmeals, one would not expect the price of fishmeal to be much influenced by increased demand from aquaculture, since the price is determined by total demand for oilmeals, of which demand from aquaculture is just a very tiny share.

To determine fishmeal's position in the oilmeal market, we will investigate its relationship to soyameal, since this clearly is the largest of the vegetable meals. The most obvious procedure would be to estimate demand equations and evaluate the cross-price elasticities. However, although there exist exchanges that give price data of good quality, it is extremely difficult if not impossible to obtain reasonable quantity data, as in most global markets.[28] Analysis of the relationships between prices will therefore be the preferred tool here, even though this does not give as much information as demand analysis. However, it will allow us to determine whether the products are not substitutes, are perfect substitutes or are imperfect substitutes.

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[27] Indications that these markets are integrated can be found in Vukina and Anderson (1993) and Gjerde (1989), who use soya futures to hedge fishmeal prices.

[28] This is what has given rise to the so-called Armington bias when estimating import demand, when one cannot account for domestic use of domestic production (Winters, 1984). When analyzing a global market rather then import demand to a single country, this problem becomes even more severe.

We use fishmeal and soyameal prices reported on a monthly basis from Europe and the US, in the period spanning from January 1981 to April 1999. The European prices are reported from Hamburg, and are denoted as Fish_Ham and Soya_Ham. In addition we use fishmeal prices from Atlanta, Georgia, denoted as Fish_Atl, and soyameal prices reported from Decatur, Illinois, denoted as Soya_Dec. The prices are shown in Figure 6. Note that the fishmeal prices are substantially higher than the soyameal prices. This is primarily because of the higher protein content. If one adjust for the protein content, most of this difference disappears. This period is interesting for at least two reasons: Firstly, there have been some extreme situations for the fishmeal production in this period due to low raw material supply, including *El Niños* in 1982-83, 1986-88, 1991-92 and finally in 1997-98, with the first and the last being the most severe. This makes it interesting to compare how the fishmeal and soyameal markets have interacted during these extreme periods. Secondly, the intensive aquaculture has experienced a tremendous growth in this period.[29] If the fishmeal primarily is demanded due to its special attributes, this should show up as the fishmeal and soyameal being different market segments during this period.

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[29] It is of interest to note that in the papers considering aquaculture even as late as the mid 1980s, extensive farming technologies like ranching seems to have been regarded as more realistic than intensive aquaculture, see e.g. Anderson (1985) and Anderson and Wilen (1985).

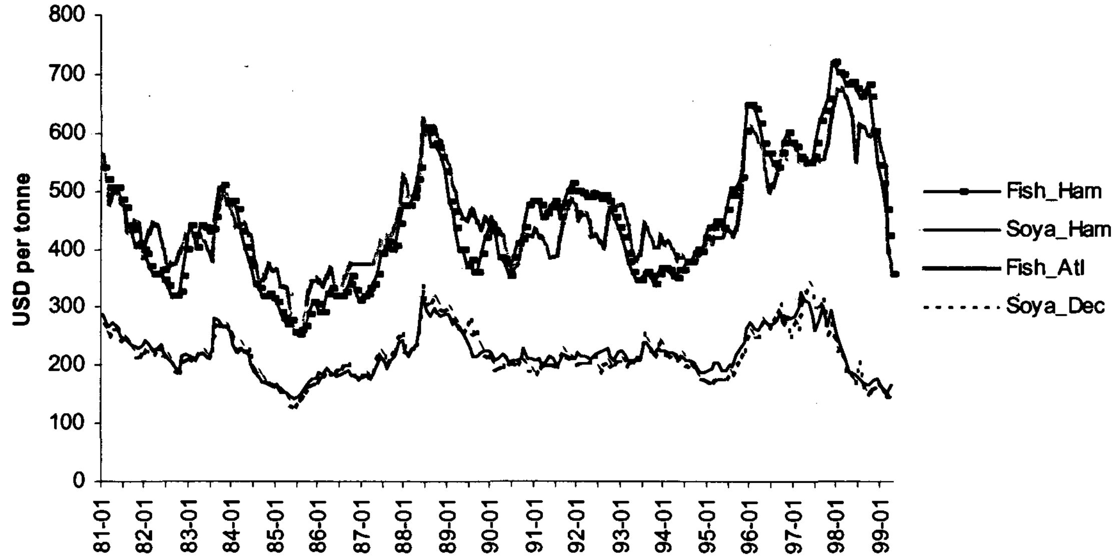

Figure 6. Monthly fishmeal and soybean meal price data from Hamburg (Ham), Atlanta (Atl) and Decatur (Dec) in the period of January 1981 to April 1999 (Source: OilWorld)

Table 1. Augmented Dickey-Fuller (ADF) tests for unit roots

Variable	*Var. in levels*	*Var. in 1. diff.*
Fish_Ham	-3.2486 (5)	-3.8090** (4)
Soya_Ham	-3.0824 (6)	-4.7883** (5)
Fish_Atl	-2.9874 (10)	-3.6270** (9)
Soya_Dec	-2.8635 (6)	-4.8965** (5)

*** indicates significant at a 1% significance level. The number in parenthesis is the number of lags used in ADF test, which is chosen on the basis of the highest significant lag out of 12 lags that were used initially. The tests for variables in levels include a constant and a trend, while in first differences only a constant is included.*

Before a statistical analysis of the relationships can be carried out, we must investigate the time series properties of the data. Dickey-Fuller tests were carried out for the price series. The lag length was chosen as the highest significant lag. All prices are found to be nonstationary, but stationary in first differences (Table 1). Hence, cointegration analysis is the appropriate tool when investigating the relationships between the prices.

3.2 Market integration

Analysis of relationships between prices has a long history in economics, and many market definitions are based on the relationship between prices. For instance, in a book first published in 1838 Cournot states: "It is evident that an article capable of transportation must flow from the market where its value is less to the market where its value is greater, until difference in value, from one market to the other, represents no more than the cost of transportation" (Cournot, 1971). While this definition of a market relates to geographical space, similar definition are used in product space, but where quality differences plays the role of transport costs (Stigler and Sherwin, 1985; Sutton, 1991). The main arguments for why this is the case, are either arbitrage or substitution.

The basic relationship to be investigated when analyzing relationships between prices is

$$\ln p_{1t} = \alpha + \beta \ln p_{2t} \qquad (5)$$

where α is a constant term (the log of a proportionality coefficient) that captures transportation costs and quality differences and β gives the relationship between the prices.[30] If β=0, there are no relationship between the prices, while if β=1 the Law of One Price holds, and the relative price is constant. In this case one can say that the goods in question are perfect substitutes. If β is greater than zero but not equal to one there is a relationship between the prices, but the relative price is not constant, and the goods will be imperfect substitutes.[31]

Equation (5) describes the situation when prices adjust immediately. However, often there will be a dynamic adjustment pattern, This can be accounted for by introducing lags of the two prices (Ravallion, 1986). It should here be noted that even when dynamics are introduced, the long-run relationship will have the same form as equation (5). One can also show that

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[30] In most analysis it is assumed that transportation costs and quality differences can be treated as constant. However, this can certainly be challenged, see e.g. Goodwin, Grennes and Wohlgenant (1990), since if e.g. transportation costs are not constant, this can cause rejections of the Law of One Price.

[31] One can also show that if β<0, this implies a complementary relationship between the two goods.

there is a close relationship between market integration based on relationships between prices and aggregation via the composite commodity theorem (Asche, Bremnes and Wessells, 1999). In particular, if the Law of One Price holds the goods in question can be aggregated using the generalized commodity theorem of Lewbel (1996).

Since the late 1980s, one has become aware that when prices are nonstationary, traditional econometric tools cannot be used, since normal inference theory breaks down (Engle and Granger, 1987). Cointegration analysis is then the appropriate tool. In early studies, single equation Engle and Granger tests (Engle and Granger, 1987) were used. However, as these have several weaknesses, the system based Johansen test (Johansen, 1988) is currently the preferred tool. For instance, the Engle and Granger test do not allow testing of the *LOP* hypothesis, while this is easily done using the Johansen test.[32][33] Since our price series seems to be nonstationary, we will use this approach.

The Johansen test is based on a vector autoregressive (VAR) system. A vector, x_t, containing the N variables to be tested for cointegration is assumed to be generated by an unrestricted k^{th} order vector autoregression in the levels of the variables;

$$\mathbf{x}_t = \Pi_1 \mathbf{x}_{t-1} + \ldots + \Pi_k \mathbf{x}_{t-k} + \mu + e_t, \qquad (6)$$

where each of the Π_i is a (NxN) matrix of parameters, μ a constant term and $\varepsilon_t \sim iid(0,\Omega)$. The VAR system of equations in (6) written in error correction form (ECM) is;

$$\Delta \mathbf{x}_t = \sum_{i=1}^{k-1} \Gamma_i \Delta \mathbf{x}_{t-i} + \Pi_K \mathbf{x}_{t-k} + \mu + e_t \qquad (7)$$

with $\Gamma_i = -I + \Pi_1 + \ldots + \Pi_i$, $i = 1, \ldots, k-1$ and $\Pi_K = -I + \Pi_1 + \ldots + \Pi_k$. Hence, Π_K is the long-run 'level solution' to (6). If x_t is a vector of $I(1)$ variables, the left-hand side and the

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[32] Asche, Bremnes and Wessells (1999) is a recent example of this approach.

[33]

first (k-1) elements of (7) are $I(0)$, and the last element of (7) is a linear combination of $I(1)$ variables. Given the assumption on the error term, this last element must also be $I(0)$; $\Pi_K x_{t-k} \sim I(0)$. Hence, either x_t contains a number of cointegration vectors, or Π_K must be a matrix of zeros. The rank of Π_K, r, determines how many linear combinations of x_t are stationary. If $r=N$, the variables in levels are stationary; if $r=0$ so that $\Pi_K=0$, none of the linear combinations are stationary. When $0<r<N$, there exist r cointegration vectors—or r stationary linear combinations of x_t. In this case one can factorize Π_K; $-\Pi_K = \alpha\beta'$, where both α and β are $(N\times r)$ matrices, and β contains the cointegration vectors (the error correcting mechanism in the system) and α the adjustment parameters. Two asymptotically equivalent tests exist in this framework, the *trace* test and the *maximum eigenvalue* test, of which the *trace* test is considered the more robust (Cheung and Lai, 1993).[34]

The Johansen procedure allows hypothesis testing on the coefficients α and β, using likelihood ratio tests (Johansen and Juselius, 1990). In our case, it is restrictions on the parameters in the cointegration vectors β which is of most interest. More specifically, in the bivariate case there are two price series in the x_t vector. Provided that the price series are cointegrated, the rank of $\Pi = \alpha\beta'$ is equal to 1 and α and β are 2x1 vectors. Of particular interest is the Law of One Price (LOP), which can be tested by imposing the restriction $\beta'=(1,-1)'$. In the multivariate case when all prices have the same stochastic trend, there must be n-1 cointegration vectors in the system and each cointegration vector must sum to zero for the LOP to hold. It then follows from the identification scheme of Johansen and Juselius (1992) that each cointegration vector can be represented so that all but two elements are zero.

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[34] The critical values for these tests are nonstandard, and are tabulated in Johansen and Juselius (1990).

When the identifying normalization is imposed in the case with four price series, one representation of the matrix of cointegration vectors is:

$$\beta = \begin{bmatrix} 1 & 1 & 1 \\ -\beta_1 & 0 & 0 \\ 0 & -\beta_2 & 0 \\ 0 & 0 & -\beta_3 \end{bmatrix} \tag{8}$$

That is, one can represent the system with *n* prices with *n*-1 pairwise relationships. If all β parameters are equal to 1, the *LOP* holds for the whole system. Hence, in a market delineation context, multivariate and bivariate tests can in principle provide the same information (Asche, Bremnes and Wessells, 1999). However, the two approaches have different statistical merits. Using a multivariate approach, one is exposed what Hendry (1995, p. 313) labels the "curse of dimensionality" in dynamic models, since one with a limited number of observations and thereby degrees of freedom will have to choose between number of lags and number of variables. In bivariate analysis one is less exposed to this problem, but one may obtain several, possible conflicting, estimates of the same long-run relationships. We will therefore estimate both a multivariate system and bivariate systems.

Recently, a number of studies have used cointegration analysis to investigating relationships between prices. Examples related to seafood products are Gordon, Salvanes and Atkins (1993), Bose and McIlgrom (1996), Gordon and Hannesson (1996), Asche, Salvanes and Steen (1997), Asche and Sebulonsen (1998) and Asche, Bremnes and Wessells (1999).

3.4 Empirical results

We start out our empirical analysis by performing a multivariate Johansen test for all prices, i.e. the European and the US fishmeal and soyameal prices. The test is specified with four lags, a restricted intercept and 11 seasonal dummies. The intercept is restricted to only enter the long-run equations of the system.[35] A LM-test against autocorrelation up to the 12th order cannot be rejected for the system with four lags.[36] Hence, four lags seem sufficient to include all dynamics. However, we cannot reduce the laglength further without getting problems with dynamic misspecification. The results from the multivariate test are reported in Table 2. The trace test concludes with 3 cointegration vectors. The max test concludes with two cointegration vectors at a 5% significance level, but with three at a 10% significance level. Given that all prices are cointegrated in the bivariate tests reported bellow, we therefore conclude with three cointegration vectors and one stochastic trend in the system. We find weak evidence against the LOP in the system as a likelihood ratio test distributed as $\chi^2(3)$ produces a test statistic of 8.33 with a p-value of 0.040. Hence, we can reject the null at a 5% level, but not at a 4% level.

Table 2. Multivariate Johansen tests of fishmeal and soyameal prices from Europe and USA

H_o:	*Max test*	*95% critical value*	*Trace test*	*95% critical value*
p==0	55.82**	28.1	112.2**	53.1
p<=1	33.99**	22.0	56.38**	34.9
p<=2	13.84	15.7	22.39*	20.0
p<=3	8.65	9.2	8.65	9.2

** indicates significant at a 5% significance level while * indicates significant at a 1% significance level.*

Given the *El Niños* and the increased demand for fishmeal from aquaculture in our data sample, parameter stability is also of interest. Clements and Hendry (1995) and Hendry (1995) argue that most parameter changes are in the intercept, so checking constancy of the constant term should be the focus of tests for parameter stability. In dynamic models like ours,

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[35] A likelihood ratio test for whether a trend should be allowed in the short-run dynamics is distributed as $\chi^2(1)$ with a critical value of 3.84 at a 5% level. With a test statistic of 0.02 we cannot reject the null hypothesis that the trend should be excluded.

[36] For the system the LM test against autocorrelation up the 12th order is distributed as F(112,622), and gives a test statistic of 1.02 with a p-value of 0.445.

this might also be important since if one is to investigate parameter stability for all parameters, one increases the likelihood substantially for dimensionality problems. We will therefore follow this approach and test against a structural break in the constant terms in January 1991, which is approximately mid sample. By choosing mid sample as break point we get two *El Niños* in each of the samples. The test is distributed as $F(3,185)$ and gives a test statistic of 1.32 with a p-value of 0.2649. Hence, this test does not provide any evidence against the null hypothesis of no structural break.

The results from the bivariate cointegration tests are reported in Table 3. The variables are denoted as Fish_Ham and Soya_Ham for fishmeal and soyameal prices reported from Hamburg, Fish_Atl for fishmeal prices in Atlanta and Soya_Dec for soyameal prices in Decatur. The *max* test and the *trace* test both give evidence of one cointegration vector for all pairs of prices. Hence, also these tests indicate that there is one stochastic trend in the system.

Tests for the LOP from the bivariate Johansen tests are also reported in Table 3. All, but one test, do not reject the *LOP* hypothesis at a 5% level, while one test barely rejects the null hypothesis at a 5% level as the p-value is 0.466. Somewhat surprising, this is the test in the relationship between the two fishmeal prices. This might suggest that the different regional markets for fishmeal may be less integrated than the markets for the better storable commodity soyameal. However, the evidence against the LOP is not strong, but it is worthwhile to note that this is then most likely the relationship the causes the possible deviations against the LOP in the multivariate test.

We can conclude that the cointegration tests indicate that the four prices follow the same stochastic trend. Accordingly, fishmeal and soyameal compete in the same market. Moreover, the LOP seems to hold, or at least is very close to hold as the evidence against it is not very strong. This implies that long-term relationships between these prices, the relative prices, is constant, and therefore also that the generalized composite commodity theorem holds. These results suggest that fishmeal and soyameal are strong substitutes. It is therefore the total demand for fish and soyameal, possibly together with the demand for other oilmeals that determines the price of these oilmeals. To influence the price of fishmeal with this market structure, the changes in demand or supply must be large enough to affect demand and supply for fish- and soyameal combined. This is important, since with this market structure, it is unlikely that increased demand for fishmeal from the aquaculture sector will lead to increased prices for fishmeal, since it has only a negligible share of this market. Hence, with this market structure, increased demand for fishmeal from the aquaculture sector will not increase fishing pressure in industrial fisheries.

Table 3. Bivariate cointegration tests with 4 lags

Variable 1	*Variable 2*	*Max test p==0*	*Max test p<=1*	*Trace test p==0*	*Trace test p<=1*	*LOP*	*Autocorr -elation*
Fish_Ham	Fish_Atl	20.71**	7.336	28.05**	7.336	0.0466*	0.1651
Fish_Ham†	Soya_Ham	20.13*	8.394	28.53**	8.394	0.4991	0.2270
Fish_Ham†	Soya_Dec	17.74*	6.479	24.22*	6.479	0.3402	0.6923
Fish_Atl†	Soya_Ham	49.69**	7.001	56.69**	7.001	0.7688	0.5811
Fish_Atl†	Soya_Dec	58.24**	6.261	64.5**	6.261	0.8349	0.4313
Soya_Ham	Soya_Dec	26.14**	6.839	32.98**	6.389	0.0590	0.0818

** indicates significant at a 5% significance level while ** indicates significant at a 1% significance level.*

4. Concluding remarks

Increased demand for fishmeal from a growing aquaculture sector has the potential to increase fishing pressure in industrial fisheries. However, if this is to be the case, the fisheries must be poorly managed or not managed at all, and there can be no close substitutes to fishmeal. The most important fish stocks in reductional fisheries can today be described as regulated open access. If this management is efficient, increased demand from aquaculture cannot be a threat to the fish stocks. However, there are many indications that quotas are set higher then biological recommendations and that quotas might be overfished. Hence, the true situation might not be too far from open access. If this is the case, increased demand for fishmeal may well increase fishing pressure.

However, poor fisheries management is not sufficient to cause increased demand for fishmeal to lead to increased fishing pressure. It must also be the case that there are no close substitutes to fishmeal. Our analysis indicates that fishmeal is part of the large oilmeal market, and in particular, that it is a close substitute to soyameal. Hence, it is total supply and demand for oilmeals, of which fishmeal makes up only 4%, which determines prices for fishmeal. With this market structure, increased demand for fishmeal from aquaculture cannot have any effect on fishmeal prices, and accordingly not lead to increased fishing pressure.

Our results indicate that increased demand for fishmeal cannot have led to increased fishing pressure in industrial fisheries because of the market structure for fishmeal. However, demand for fishmeal from aquaculture has grown from basically nothing to 17% of total production in only twenty years time. If demand for fishmeal from the aquaculture sector continues to grow it is possible that the market structure may change. However, this does not have to be the case, since it is not clear that even the demand for fishmeal from the aquaculture sector is mainly because of the unique characteristics of fishmeal. What is clear though is that the current market structure prevents increased demand for fishmeal to have a negative impact on industrial fish stocks. Moreover, the only measure that can ensure that demand for fishmeal does not have a negative impact on these fish stocks due to increased fishing pressure at any time in the future is good fisheries management.

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PAPER 3

Market Integration and Exchange Rates in Primary Commodity Markets

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Abstract

In most recent international market integration studies exchange rates have been conspicuous by their absence. In this paper we revisit Richardson (1978) that addresses the issue of exchange rate pass-through together with market integration, but in a multivariate cointegration framework. In addition to standard test like the law of one price and exchange rate pass-through, this allow us to test common assumptions like leading price, central markets and exogeneity of exchange rates. This approach is particularly suited when studying markets for primary products. We provide empirical examples using salmon in Japan and fish meal exports from Peru to Germany.

Keywords: Market integration, exchange rate pass-through, law of one price, leading price, exogeneity.

1. Introduction

Exchange rates play an important role in international trade due to their influence on relative prices of commodities. Yet, in market integration studies the role of exchange rates is often disregarded. By omitting exchange rates one loses information about the impact currency movements can have on the international competitiveness of industries. In this study we combine Richardson's (1978) market integration framework with the Johansen (1988, 1991) multivariate cointegration procedure. This gives at least two important advantages. In Richardson's framework there is a simultaneity problem because economic theory does not give any indication of the direction of the causality between the prices. Such a problem is avoided in the Johansen framework since it is based on a vector autoregressive (VAR) model that allows all variables to be treated as endogenous. Furthermore, one can test for weak exogeneity, and thereby test whether any simpler specifications, including a single equation specification, is appropriate. Exogeneity tests have economic interest as an exogenous price variable can be interpreted as a leading price.[37] One can also test the commonly made assumption of exogeneity of exchange rates. The 'law of one price' and exchange rate pass-through are also testable hypotheses in this framework.

This study represents a departure from price discrimination issues of manufactured goods markets, which covers the main bulk of exchange rate pass-through studies. Instead the focus is on market integration, an issue that is most relevant in primary goods markets. In this respect we believe the traditional framework of Richardson (1978) has a role to play in modern analysis, particularly for primary commodity markets. It has the same data requirements as Knetter's approach (1989, 1993), but it contains slightly different information. Homogenous products need not be assumed, but this is a testable hypothesis

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[37] Leading price corresponds to the central market hypothesis in the geographical dimension.

together with exchange rate pass-through. More generally, the Johansen procedure is a more reliable method for inference when using nonstationary variables, since one is likely to overreject the null hypothesis substantially when using standard inference theory.

Somewhat surprisingly exchange rates seem to have disappeared from market integration research, particularly after cointegration tests became the main econometric tool, as it has become common to assume complete exchange rate pass-through (Goodwin, Grennes, and Wohlgenant 1990, Baffes 1991, Asche, Bremnes, and Wessells 1999, Zanias 1999).[38] Complete exchange rate pass-through combined with constant relative prices, so that the 'law of one price' holds, entails perfect commodity arbitrage. The findings of currency changes being completely passed through on prices is, however, mixed in Isard (1977), Richardson (1978), and Giovannini (1988). The related purchasing power parity literature casts even more doubt on this assumption, although the inclusion of tradable and nontradable goods in PPP studies makes the comparison more complicated (Rogoff, 1996; Feenstra and Kendall, 1997). There are several possible explanations why exchange rates are not fully passed through in primary goods markets, even for perfect substitutes. As Goldberg and Knetter (1997) note, an integrated market need not be perfectly competitive as there can be opportunities to sell products over marginal cost. Some form of product differentiation or competitive advantage may open up for pricing over marginal cost. Trade restrictions are perhaps an even more important source of inefficiency in commodity markets (Goldberg and Knetter, 1999).

Exchange rates can themselves affect world prices by influencing trade flows with changing relative prices. In particular U.S. dollars can have such an effect due to the importance of the

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[38] More recent studies of exchange rates and goods markets have focused more on issues like market power and price discrimination in relation to manufactured goods. This includes most of the literature covering two closely related subjects, exchange rate pass-through and pricing-to-market (Knetter, 1989, 1993; Feenstra, 1989; Froot and Klemperer, 1989; Menon, 1996; Yang, 1997).

North American market for many commodities (Sachs, 1985; Dornbusch, 1985; Côté, 1987). Production costs are, however, less apt to alter with currency changes since production of primary commodities usually depends on domestic inputs, contrary to many manufactured goods. The fact that we can rule out direct effects of currency changes on production costs contributes to a larger degree of transparency.

The exchange rate pass-through literature has evolved with the renewed interest it received following Krugman's (1987) pricing-to-market hypothesis. Early studies like Knetter (1989; 1993) test the hypothesis assuming that products are homogenous using only price and exchange rate data. More recent studies like Goldberg and Knetter (1999) provide more information, but at the cost of higher data requirements.

We present two empirical applications of the market integration framework, and have deliberately chosen markets we believe contain homogenous goods. The reason is that there is a tendency of rejecting the 'law of one price' in earlier market integration studies, and inference might then best be illustrated by being able to maintain the 'law of one price' in correspondence with prior beliefs. The first is the Japanese market for imported salmons, where there have been attempts to link declining sockeye prices with increased imports of farmed salmon trout and coho from Norway and Chile. We investigate whether farmed salmon trout and coho might have displaced wild sockeye in Japan. The other empirical application investigates pricing behaviour of Peru, the world's largest fish meal producer and exporter. In particular, we investigate whether changes in global fish meal demand have opened up for markup pricing for Peruvian fish meal exports to the German market. For both of these applications we investigate a number of hypotheses like exchange rate pass-through, leading price, 'law of one price' and exogeneity of exchange rates in order to disentangle the market relationships.

The theoretical and methodological aspects of the market integration framework are presented in the next two sections, before we proceed with two empirical applications in Sections 4 and 5. Concluding remarks follow in Section 6.

2. Market integration

Following Richardson (1978), the relationship between two prices can be specified as

$$P_t^1 = P_t^{*2\beta} E_t^{\gamma} W^{\phi} e^{v_t} \tag{1}$$

Superscript 1 denotes the price of a good from one producer in his currency, hereafter named the importer's currency, while superscript 2 denotes the price from another producer, hereafter named the exporter.[39] A * superscript indicates that the price is in the exporters currency, and E is the exchange rate in the importers currency per unit of the exporter's currency. W is transaction costs and v is an error term that captures deviations from the potential long-run relationship. The coefficients β, γ, ϕ are parameters to be determined. In most empirical analyses of the transaction costs W is assumed to be constant so that it can be represented by a constant term, a. It is also common practice to transform the data to natural logarithms. The long-run relationship to be investigated when transportation costs are assumed constant can then be expressed as

$$p_t^1 = \alpha + \beta p_t^{2*} + \gamma e_t + v_t \tag{2}$$

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[39] There are several possible sets of prices that are meaningful to test, including prices from the same exporter to different import markets, prices in one import market from different exporters, and prices in different markets.

where the relationship is arbitrarily normalized on price.[40] Note that e in equation (1) is the exponential function and not a stochastic residual term, while e_t in equation (2) is the logarithm of the exchange rate.

The first hypothesis of interest in this equation is whether there is a relationship between the prices. This corresponds to a test for the null hypothesis that there is no relationship and is given as $H_0{:}\beta=\gamma=0$. If the data series are nonstationary, this corresponds to a test of whether the price series are cointegrated, or whether the error term v is stationary. If there is a long-run relationship, the next hypothesis of interest is whether $\beta=\gamma$, given that the parameters are different from zero. If these parameters are equal, we can conclude that the exchange rate pass-through is complete, and one can express the relationship in a common currency.[41] The final hypothesis of interest is whether $\beta=\gamma=1$, i.e., whether the relative price is constant or the 'law of one price' holds.

When investigating the relationship between prices a simultaneity problem arises because economic theory gives no indication about the direction of the relationship. Moreover, there are good reasons to expect a leading price or a central market in both directions depending on the market studied, as well as simultaneous systems. In most cases the estimated equations will also contain several lags, as there may be adjustment costs. If one is interested in establishing a leading price, one often runs the regression in both directions. These specifications are problematic as each single equation specification often depends on an exogeneity assumption. In the international trade literature exchange rates are normally assumed to be exogenous as each good makes up a minor share of a country's trade, although

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[40] Please note that if we rather normalise on the export price, the sign on the exchange rate parameter will be reversed.

[41] If $\beta=\gamma$, one can write $\beta p+\gamma e$ as $\beta(p+e)=\beta\ln(P^*E)$.

one can also argue about this assumption (Richardson, 1978). When one specifies the relationship in a multivariate system these problems can be avoided, and the exogeneity assumptions will be testable hypotheses. More precisely one can test for weak exogeneity, which is both a necessary and sufficient condition for inference (contrary to Granger causality which is neither; see Engle, Granger and Richard, 1983). We now turn to the methodological aspect of the study.

3. Econometric approach

We will investigate the relationships between prices at different stages in the value chain using the Johansen test (1991). The Johansen test is based on a VAR system. A vector, x_t, containing the N variables to be tested for cointegration, is assumed to be generated by an unrestricted kth order vector autoregression in the levels of the variables;

$$\mathbf{x}_t = \Pi_1 \mathbf{x}_{t-1} + \ldots + \Pi_k \mathbf{x}_{t-k} + \Phi D_t + \mu + e_t \tag{3}$$

where each Π_i is a $(N \times N)$ matrix of parameters, μ a constant term and $\varepsilon_t \sim niid(0,\Omega)$. The VAR system of equations in (4) written in error correction form (ECM) is;

$$\Delta \mathbf{x}_t = \sum_{i=1}^{k-1} \Gamma_i \Delta \mathbf{x}_{t-i} + \Pi_K \mathbf{x}_{t-k} + \mu + e_t \tag{4}$$

with $\Gamma_i = -I + \Pi_1 + \ldots + \Pi_i$, $i = 1, \ldots, k-1$ and $\Pi_K = -I + \Pi_1 + \ldots + \Pi_k$. Hence, Π_K is the long-run 'level solution' to (3). If x_t is a vector of $I(1)$ variables, the left-hand side and the first (k-1) elements of (4) are $I(0)$, and the last element of (4) is a linear combination of $I(1)$ variables. Given the assumption on the error term, this last element must also be $I(0)$; $\Pi_K x_{t-k} \sim I(0)$. Hence, either x_t contains a number of cointegration vectors, or Π_K must be a matrix of zeros. The rank of Π_K, r, determines how many linear combinations of x_t are stationary. If $r = N$, the variables in levels are stationary; if $r = 0$ so that $\Pi_K = 0$, none of the linear combinations are stationary. When $0 < r < N$, there exist r cointegration vectors - or r stationary linear combinations of x_t. In this case one can factorise Π_K; $-\Pi_K = \alpha\beta'$, where both α and β are ($N \times r$) matrices, and β contains the cointegration vectors (the error correcting mechanism in the system) and α the factor loadings. Two asymptotically equivalent tests exist in this framework; the trace test and the maximum eigenvalue test. In our empirical applications, the x_t vector contains three data series, the two prices and the exchange rate. We will expect to find one cointegration vector if there is a relationship between the two markets.

The Johansen procedure allows hypothesis testing on the coefficients α and β, using likelihood ratio tests (Johansen and Juselius, 1990). Provided that the data series are cointegrated and we find one cointegration vector, the rank of $\Pi = \alpha\beta'$ is equal to 1 and α and β are (3×1) vectors. A test of full exchange rate pass-through is then a test of whether $\beta'=(1,-b,b)'$ and is distributed as $\chi^2(1)$, while a test for the 'law of one price' is a test of whether $\beta'=(1,-1,-1)'$ and is distributed as $\chi^2(2)$. The factor loadings α are of interest as they contain information about exogeneity (Johansen and Juselius, 1990), and therefore also about leading prices or central markets. If a row in α contains only zeros (or in our case one element since α is a column vector), the price in question will be weakly exogenous, or decided outside of the system. Hence, if the factor loading parameter in the equation for the exchange rate is zero, the data indicate that the exchanges rate is decided outside of the system. Furthermore, if the factor loading parameter associated with one of the prices is zero, this price will be determined outside of the system, and will therefore be the leading price. With one cointegration vector, at least one factor loading parameter must be different from zero (Johansen and Juselius, 1990). Also note that only in the case when just one factor loading parameter is different from zero will there be no simultaneity problems if a system is represented with a single equation specification (normalised on the correct variable). On this background we may now proceed with two case studies with application of the market integration framework.

4. Empirical Application: Wild and farmed salmon in the Japanese market

4.1 Background

In the first empirical application we estimate import demand for high-valued frozen salmon in Japan. Until the late 1980s, this flow consisted almost exclusively of wild sockeye salmon from North America, primarily Alaska. However, during the 1980s salmon farming was a growing industry. In the early 1990s, there were considerable growth in production of farmed salmon trout and coho in Chile and Norway, which was largely exported to Japan. By the late 1990s, the Japanese imports of both farmed salmon trout and farmed coho were larger than imports of frozen wild-caught North American salmon. Throughout this period, Alaskan fishermen have seen their prices for salmon decreasing. It is therefore of interest to investigate to what extent farmed salmon and trout have become substitutes for wild North American salmon in its principal market, Japan.[42]

After several technological breakthroughs, salmon farming became a viable commercial sector during the 1980s (Bjørndal, 1990). As the pioneers were European, the preferred species was Atlantic salmon, although operators quickly started farming salmon trout and (in the Pacific) coho, targeting the Japanese market. The main producers of salmon trout are Norway and Chile, while Chile is virtually the only producer of farmed coho. These species are suitable for Japanese tradition because of their deep, red flesh. Sockeye is the salmon species with the deepest red colour, traditionally favoured by Japanese consumers. However,

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[42] As Atlantic salmon is mainly imported fresh to Japan, and is not considered as one of the "red-meat" salmons like salmon trout, coho and sockeye, we have not included it in the discussion.

sockeye are not as biologically feasible to farm on a commercial basis. In the early 1990s, Japanese imports for the farmed species increased rapidly. Of the imported high-valued species, the market shares in 2000 were 35% for salmon trout, 34% for farmed coho, and 31% for sockeye. The market share for imported farmed coho and salmon trout were close to zero as late as 1990. World salmon prices have decreased substantially over the period, which this is primarily due to productivity growth and increased production of farmed salmon (Tveteras, 2000). The objective of this analysis is to ask, given this newly-structured market for salmon in Japan, does the presence of farmed salmon in the Japanese market influence prices for wild salmon from Alaska?[43]

4.2 Data and empirical results

We use Japanese import data on a monthly basis from January 1994 to December 2000. The data contains import values and quantites for salmon trout, Chilean coho, and North American sockeye, with import unit values in Japanese Yen as prices shown in Figure 1. Prices are changed into their domestic currencies for the cointegration tests, as reported in Table A1 in the Appendix. North American sockeye is an aggregate of Alaskan and Canadian sockeye, of which the Canadian catches are a small part. The sockeye fisheries take place in summer, and the exports to Japan throughout the year can therefore be viewed as inventory dissipation of frozen sockeye. Since all coho in Chile is farmed and virtually all production of farmed coho is done in Chile, this variable can also be labeled farmed coho. All production of salmon trout is farmed, while all North American sockeye are wild-caught.

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[43] There exist a number of studies on the global salmon market like Bjørndal, Knapp, and Lem (2003), Asche (2001), Asche, Bremnes, and Wessells (1999), Bjørndal, Salvanes, and Gordon (1994); DeVoretz and Salvanes (1993), Gordon, Salvanes, and Atkins (1993).

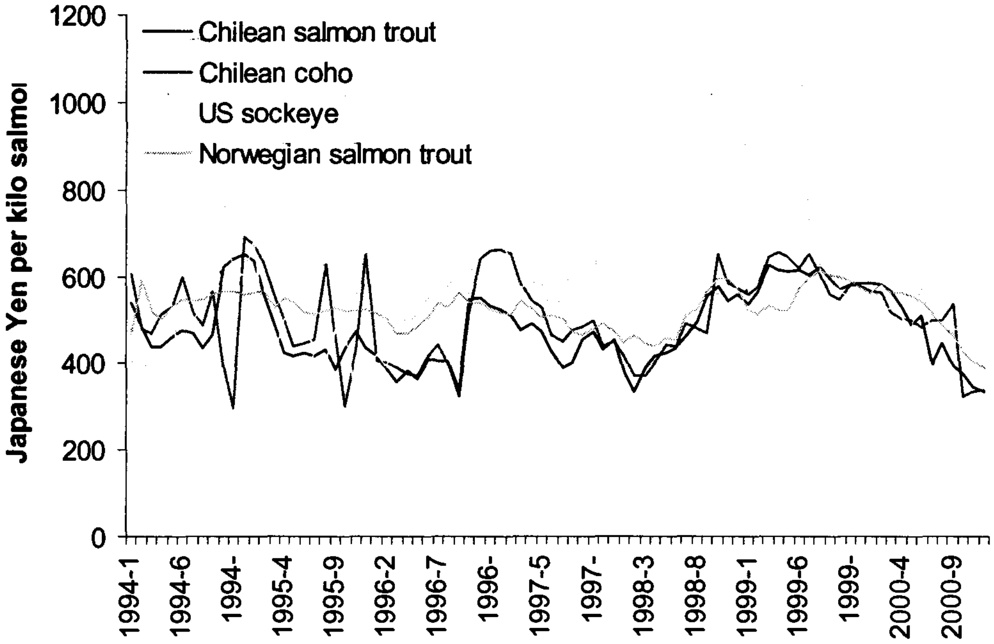

Figure 1. Japanese import prices of salmonid species from January 1994 to December 2000 (Source: Table A1, Appendix)

The first step in the analysis is to investigate the time series properties of the data. In Table 1 are the results of the Augmented Dickey-Fuller tests, reporting third lag statistics. The NOK/CLP is the exchange rate between Norwegian Kroner and Chilean Pesos. The null hypothesis of unit root is accepted in levels for the variables, while it is rejected for the first differences indicating that all the variables are $I(1)$. This means that we can proceed with the Johansen tests, which in our framework presupposes that the data are $I(1)$ in order for the hypothesis tests to be meaningful.

Table 1. Augmented Dickey-Fuller tests

Data series; *logs of prices and exchange rates*	Test statistic, levels	Test statistic, first differences
Chilean salmon trout	-1.6572	-3.9904**
Chilean coho	-1.9779	-5.0158**
US sockeye	-1.9157	-4.6751**
Norwegian salmon trout	-2.0012	-3.7414**
NOK/CLP	-2.7721	-4.9436**
USD/CLP	0.37624	-5.5569**

** indicates significant at a 5% level and ** indicates significant at a 1% level*

It is well known that cointegration vectors are identifiable only up to a non-singular transformation (Engle and Granger, 1987). To avoid estimation of redundant vectors, the price of Chilean salmon trout price is included in all reported tests. In Table 2 are the cointegration results for Norwegian and Chilean salmon trout in the Japanese market. The VAR is specified with three endogenous variables, the respective salmon trout prices and the exchange rate. Three lags are sufficient to avoid autocorrelated errors. With a trace statistic of 29.84 cointegration is accepted at a 5 percent significance level.

Table 2. Cointegration tests between Chilean and Norwegian salmon trout prices, and exchange rate (CLP/NOK)

Ho:rank=p	Trace test	Critical value
p= 0	29.84*	29.7
p<= 1	12.94	15.4
p<= 2	3.529	3.8

LM(12)^{a} autocorrelation	Full exchange rate pass-through	Law of one price
1.2673 (0.1161)^{b}	1.7007 (0.1922)^{b}	3.3857 (0.1840)^{b}

Exchange rate (CLP/NOK) weakly exogenous	Chilean trout w/Exchange rate weakly exogenous	Norwegian trout w/Exchange rate weakly exogenous
0.32931 (0.5661)	2.5204 (0.2836)	8.6895 (0.0130) *

** indicates significant at a 5% level*

^{a} LM is a Lagrange Multiplier tes t against autocorrelation up to 12 lags

^{b} p-values in parentheses

With a test statistic of 1.7007, the complete exchange rate pass-through hypothesis cannot be rejected. The test can be interpreted as whether changes in the exchange rate between Chilean pesos (CLP) and Norwegian kroner (NOK) are fully reflected in the price relationship, so that changes in exchange rate do not change the relative prices in the long run. The 'law of one price' hypothesis cannot be rejected, as one would expect for a homogenous commodity. The final test statistics in Table 2 address the question of exogeneity. These tests indicate that

Chilean salmon trout is a leading indicator, which is not surprising as their production is almost twice the size of the Norwegian production. Furthermore, as expected the exchange rate is exogenous.

In Table 3 we examine the relationship between Chilean salmon trout and US Sockeye. Figure 1 shows that the main trend in the wild sockeye price tracks the prices of the farmed species except for in a period during 1998/1999. The divergence in this period must be seen in relation to a dramatic fall in sockeye catches in 1998, when they dropped to a level that was only 40 % of what it was 2 years earlier. The trace test gives one cointegration vector at a 5 % significance level, and indicates that wild salmon is integrated with the farmed salmon trout. Both complete exchange rate pass-through and the 'law of one price' hypotheses are accepted, implying that in the long run sockeye prices are constant relative to salmon trout prices. Chilean salmon trout is judged the leading price at a 5 % significance level. It most likely reflects that salmon trout has displaced sockeye in the Japanese market during the 1990s; sockeye had a 90 % market share at the end of the 1980s, but during the 1990s it has been reduced to approximately a third of the market. Again the exchange rate is exogenous.

Table 3. Cointegration tests between US sockeye and Chilean salmon trout prices, and exchange rate (USD/CLP)

Ho:rank=p	Trace test	Critical values
p= 0	30.73*	29.7
p<= 1	12.79	15.4
p<= 2	0.224	3.8

LM(12)[a] autocorrelation	Full exchange rate pass-through	Law of one price
1.2495 (0.1306)[b]	2.0474 (0.1525)[b]	1.5388 (0.4633)[b]
Exchange rate (USD/CLP) exogenous in system	US sockeye w/exchange rate (USD/CLP) exogenous in system	Chilean salmon trout w/exchange rate (USD/CLP) exogenous in system
1.0145 (0.3138)	6.3604 (0.0416)*[b]	1.1111 (0.5738)[b]

** and ** indicates significant at a 5% and 1% level*

[a] *LM is a Lagrange Multiplier test against autocorrelation up to 12 lags*
[b] *p-values in parentheses*

Finally, as a control measure we examine whether Chilean coho and salmon trout prices are integrated in the Japanese market. Given our prior knowledge of coho and salmon trout as being closely related, it is as expected that we find these prices to be cointegrated. With a trace statitistic of 27.95 the test indicates one cointegration vector at a 1 % significance level. The test for the 'law of one price' is not rejected implying that the relative prices of Chilean coho and salmon trout are constant in the long run. From the weak exogeneity test we can infer that salmon trout is the leading price, reflecting the increasing market share and preferred quality of salmon trout in the Japanese market. In the concluding section follows a discussion concerning implications for Alaskan fishermen of these results.

Table 4. Cointegration tests between Chilean coho and Chilean salmon trout

Ho:rank=p	Trace test	Critical value
p= 0	27.95**	15.4
p<= 1	3.181	3.8
LM(12)[a] autocorrelation 1.2704 (0.1592)[b]	Law of one price 1.7715 (0.1832)[b]	
Chilean salmon trout weakly exogenous (priceleader) 0.62151 (0.4305)	Chilean coho weakly exogenous (priceleader) 21.185 (0.0000) **	

** indicates significant at a 5% level*
[a] *LM is a Lagrange Multiplier test against autocorrelation up to 12 lags*
[b] *p-values in parentheses*

5. Empirical Application: The fish meal market – FOB Peru, C&F Hamburg

5.1 Background

In the second empirical application we look at whether increased production of high-quality fish meals has opened up for markup pricing of Peruvian exports to Germany, as it has reduced the availability of standard quality meals that Germany purchases. The Hamburg price is one of the most widely quoted fish meal prices, reflecting the importance of Germany as a fish meal importer. Peru has a unique role in the fish meal market, and accounts for over 50 % the global fish meal exports in 2000. With such strong position it is not unnatural to suspect Peru of having some degree of market power in the market for marine proteins. Moreover, fish meal is one of Peru's most important export products.

Traditionally fish meal was almost entirely used as a protein input in feeds for poultry and pigs. The fish meal consumption pattern has, however, changed with the expansion of intensive aquaculture production, and in 2002 a total of 34 % of the global fish meal supply went to aquaculture feeds (Barlow, 2002). Most fish meal imports to continental Europe represent the traditional use of fish meal, as a protein source in pig and poultry feeds. This is also the case for Germany where large parts of the imports are re-exported to middle and central Europe, countries which do not have any industrial aquaculture to speak of. Increased production of premium quality fish meal destined to aquaculture feeds producers can have provided Peruvian fish meal producers the opportunity to exert market power over buyers of standard quality fish meal, as less of this quality is available. Market power will, however, depend on whether demand for standard quality fish meal is inelastic, and also whether arbitrage opportunities are possible.

Fish meal makes up a valued high-protein input in the feeds of simple-stomached animals due to its favourable balance of amino acids, its vitamin B-content, and its positive effect on growth, particularly in the early stages of growth (FAO, 1983).[44] Despite the special

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[44] The beneficial growth effect of fish meal was earlier attributed to an 'Unidentified Growth Factor' (UGF). Today it is suspected that a mix of components such as selenium, vitamin B12, methionine and omega-3 fatty acids in fish meal create this beneficial effect, as one has not been able to isolate any single component as the UGF.

characteristics of fish meal it is also clear that fish meal is used as a protein input where alternative protein sources are available. Vukina and Anderson (1993) show that there is a strong relationship between the fish meal and soybean meal markets. If fish meal can easily be substituted with vegetable protein sources like soybean meal, then there is not much room for markup pricing. This might well be the case considering that pig and poultry feed producers operate with least cost formulas where many feed ingredients are interchangeable.

5.2 Data and empirical results

One way to approach the question of market power in pricing strategies is by testing for exchange rate pass-through of exporter to importer price. Preferably one should use the exporter's marginal costs, but such data are seldom available, and then price data is an alternative. Incomplete pass-through signals markup pricing since it implies that price is not constant relative to marginal costs. Adjustments of price relative to marginal cost imply that there either is a markup, or that price is below marginal costs, but the latter money-losing strategy is not a plausible in the long run. We use Peruvian FOB fish meal price and Hamburg C&F fish meal price in own currencies for standard quality meal in addition to the exchange rate between Peruvian Nuevo Soles (PEN) and Euro (EUR), as reported in Table A2 in Appendix. The dollar equivalent prices are shown in Figure 2. As we can see there have been dramatic price movements in the data period spanning from January 1994 to December 2001. The high prices in the middle of the period relates to the El Niño weather phenomenon in 1997/98, which drastically reduced the industrial fisheries and thereby fish meal production. The Peruvian and Hamburg prices are converted from US Dollar to Peruvian Nuevo Soles and Euro respectively.[45]

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[45] Oilworld Ista Mielke has provided the Hamburg fishmeal price data, while the Peruvian FOB prices are from International Fishmeal and Fish Oil Organisation.

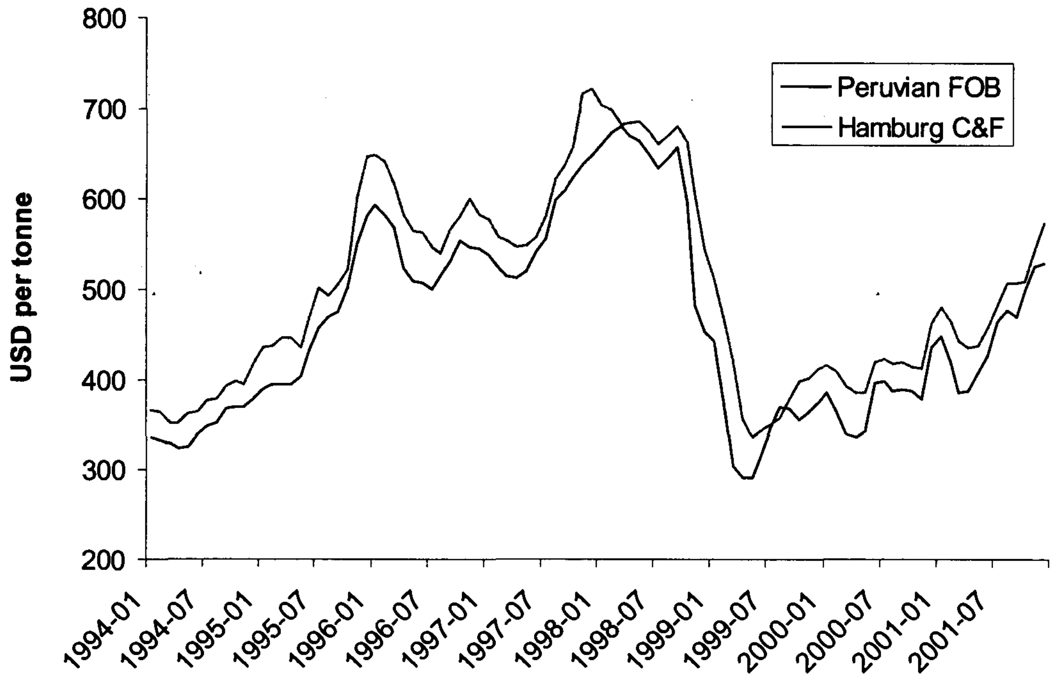

Figure 2. Peruvian FOB and Hamburg C&F fishmeal prices for standard quality meal with 64/65% protein content from January 1994 to December 2001 (Sources: Table A2, Appendix)

Table 5 shows the results from the Augmented Dickey-Fuller unit root tests, indicating that all three series are $I(1)$. Next, Table 6 reports the results from the various hypotheses tests in the same manner as for the salmon cointegration tests. Three lags are sufficient to obtain a well-behaved error term, and the trace test indicates that the series are cointegrated. The test for complete exchange rate pass-through cannot be rejected. This indicates that Peruvian fish meal producers do not have any market power to speak of in the German market for marine proteins. The 'law of one price' is barely rejected at a 5 % level, indicating high a degree of, but not full market integration.

Table 5. Augmented Dickey-Fuller tests

Data series; *logs of prices and exchange rates*	Test statistic, levels	Test statistic, first differences
Peruvian FOB fishmeal	-2.2560	0.36059**
Hamburg C&F fishmeal	-2.2724	-2.9522*
PEN/EUR	-1.8606	-5.2435**

** indicates significant at a 5% level and ** indicates significant at a 1% level*

Table 6. Cointegration tests between Peruvian FOB and Hamburg C&F fishmeal prices, and exchange rate (PEN/EUR)

Ho:rank=p	Trace test	Critical values
p== 0	45.16**	29.7
p<= 1	12.1	15.4
p<= 2	3.328	3.8

LM(12)[a] autocorrelation 0.79599 (0.8914)[b]	Full exchange rate pass-through 0.075529 (0.7834)[b]	Law of one price 6.2367 (0.0442)* [b]
Exchange rate (PEN/EUR) exogenous in system 12.032 (0.0024)** [b]	Hamburg C&F price w/exchange rate (PEN/EUR) exogenous in system 21.373 (0.0000)** [b]	Peruvian FOB price w/exchange rate (PEN/EUR) exogenous in system 5.2524 (0.0724)[b]

* and ** indicates significant at a 5% and 1% level

[a] LM is a Lagrange Multiplier test against autocorrelation up to 12 lags

[b] *p*-values in parentheses

Although Peru does not have market power we would expect the major fish meal producer to have a leading price role in the price relationship. The weak exogeneity tests confirm our expectations by rejecting the hypothesis of weak exogeneity of the Hamburg price while accepting exogeneity for the Peruvian FOB price. Somewhat surprisingly, the exchange rate is not exogenous in the system. It is safe to assume the Euro is not being influenced by the fish meal price, as fish meal is a small part of EU trade. That leaves us with the Peruvian Nuevo Soles. The result might reflect the importance of fish meal exports in the Peruvian economy. Fish meal's share of total Peruvian exports vary between 6.8 % to 15.5 % during our data period, and accordingly fish meal trade is a major source of foreign-currency income to Peru. Another possible explanation is that downturn following the El Niño in 1998 also hit other Peruvian exporting industries, and thereby jointly influenced the Peruvian currency. A correlation between the Peruvian exports of fish meal and other commodities might then explain the susceptibility of the soles to changing fish meal prices.

6. Concluding remarks

Market integration studies are of interest in primary product markets, in particular because price series are often the most available form of data. In this study we use to Richardson's (1978) framework for market integration in combination with the Johansen cointegration test. This framework allows for an array of hypotheses tests on price relationships, including explicit tests of exchange rate pass-through. This is in contrast to what is the case in most market integration studies after cointegration techniques became popular, as full exchange rate pass through is then assumed. The Johansen test is formulated in a VAR system where all variables are allowed to be endogenous. One can therefore avoid the simultaneity problem in Richardson's single equation specification. Moreover, in this framework one can test for exogeneity. This opens up for tests of hypothesis like leading prices and exogeneity of exchange rates. These hypothesis are instrumental in understanding what mechanisms drive prices, but have in the literature mostly been assumed rather then tested.

In the investigation of the key Japanese market for seafood products, the focus is on exporter-to-exporter salmon prices. Alaskan fishermen have experienced declining prices for their sockeye exports to Japan, a development that has been associated with the increasing exports of frozen farmed salmon trout and coho to the Japanese market. The tests indicate that wild sockeye together with farmed salmon trout and coho constitute a highly integrated market, since both complete exchange rate pass-through and 'law of one price' are not rejected. It also appears that wild Alaskan sockeye salmon is a price follower. Being a price follower implies that the prices Alaskan fishermen receive for their catches follows those of farmed salmon trout. In this situation, the prospects for Alaskan fishermen of experiencing an increase in sockeye prices are small. On the contrary, it is likely that prices will continue to decrease, as production costs for farmed salmons are declining.

The application to Peruvian fish meal exports to Germany represents the 'classical' exchange rate pass-through setting, where one uses the exporter's and the importer's price to measure the degree of pass-through. In combination with exogeneity test of the Peruvian fish meal price relative to the Hamburg fish meal price, we examine whether Peru is a price leader with leverage to conduct markup pricing in continental Europe. Once again the test for complete exchange rates pass-through is not rejected, while the 'law of one price' is just rejected. The results indicate that Peruvian fish meal producers have little or no market power despite its formidable position with around 50 % of global fish meal exports. They are also supportive of the privatisation that has taken place of the Peruvian fish meal industry, in that there seems to be limited market power to be gained from a national monopoly. These findings correspond with the view that it is generally difficult to conduct markup pricing in primary goods markets, which is conveyed by those market integration studies where exchange rates are left out (Goodwin, Grennes, and Wohlgenant 1990, Baffes 1991, Asche, Bremnes, and Wessells 1999, Zanias 1999).

One result that does not accord with prior expectations is the endogeneity of the Peruvian currency, Peruvian Nuevo Soles. That the fish meal price influence the Peruvian Nuevo Soles might reflect the importance of the fish processing industry in Peru. Although, as mentioned above, another explanation might be that the joint effect of Peruvian export industries hit by the El Niño in 1998 is reflected in the fish meal price's influence on the sole. Irrespective of what is the correct explanation, the endogeneity of the soles reflects the Peruvian economy's dependency on primary goods exports. More generally, this result contradicts the commonly made assumption that exchange rates are exogenous.

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Appendix

Table A1. Monthly frozen salmonid prices and exchange rates from January 1994 to December 1996 (Sources: Norwegian Seafood Export Council, Norges Bank)

Date	Chile trout (CLP)	Chile coho (CLP)	USA sockeye (USD)	Norwegian trout (NOK)	NOK/CLP	USD/NOK	USD/CLP
1994-1	2099	2367	3,708	31,24	0,017286	0,133140	0,002301
1994-2	1982	1966	3,500	41,57	0,017224	0,133424	0,002298
1994-3	1799	1908	3,998	36,43	0,017065	0,136071	0,002322
1994-4	1849	2164	4,167	35,70	0,016828	0,135775	0,002285
1994-5	1888	2173	4,135	36,95	0,016931	0,139212	0,002357
1994-6	1977	2486	5,288	37,53	0,016550	0,141263	0,002338
1994-7	2008	2213	4,931	37,69	0,016292	0,145622	0,002372
1994-8	1798	2014	5,679	37,60	0,016575	0,145724	0,002415
1994-9	1951	2367	7,293	38,43	0,016454	0,146981	0,002418
1994-10	2630	1650	7,882	37,93	0,015891	0,151019	0,002400
1994-11	2587	1207	6,219	38,86	0,016910	0,148666	0,002514
1994-12	2643	2816	6,018	38,24	0,016787	0,145875	0,002449
1995-1	2618	2783	6,847	37,67	0,016261	0,149223	0,002427
1995-2	2370	2683	4,860	37,83	0,015798	0,151646	0,002396
1995-3	2231	2556	4,659	36,67	0,015147	0,159513	0,002416
1995-4	1948	2287	5,982	40,59	0,016081	0,161600	0,002599
1995-5	1850	1942	5,884	40,00	0,016709	0,159101	0,002658
1995-6	1897	1996	6,556	38,16	0,016429	0,160349	0,002634
1995-7	1847	1999	4,536	36,35	0,016001	0,161993	0,002592
1995-8	1787	2595	4,285	34,82	0,016227	0,157739	0,002560
1995-9	1549	1842	4,728	33,52	0,015848	0,156272	0,002477
1995-10	1804	1244	4,697	32,23	0,014969	0,160316	0,002400
1995-11	1884	1717	3,101	31,98	0,015364	0,160074	0,002459
1995-12	1739	2603	3,537	32,63	0,015586	0,157428	0,002454
1996-1	1605	1555	3,973	31,10	0,015771	0,155860	0,002458
1996-2	1512	1566	3,699	30,31	0,015535	0,156128	0,002426
1996-3	1384	1514	4,450	28,31	0,015578	0,155574	0,002423
1996-4	1434	1412	4,535	28,41	0,016159	0,153856	0,002486
1996-5	1406	1440	4,864	29,85	0,015961	0,152073	0,002427
1996-6	1540	1574	5,054	30,22	0,015877	0,153111	0,002431
1996-7	1543	1684	4,966	31,78	0,015504	0,155032	0,002404
1996-8	1540	1530	5,328	31,40	0,015638	0,156028	0,002440
1996-9	1262	1202	5,495	32,93	0,015720	0,154902	0,002435
1996-10	2078	1970	5,352	31,16	0,015179	0,154216	0,002341
1996-11	2036	2363	5,946	30,54	0,015275	0,157428	0,002405
1996-12	2012	2487	5,970	29,83	0,015010	0,154660	0,002321
1997-1	1852	2343	5,869	28,30	0,015454	0,155099	0,002397
1997-2	1674	2146	5,145	27,62	0,016341	0,150975	0,002467
1997-3	1658	2029	4,673	30,16	0,015948	0,146675	0,002339
1997-4	1603	1775	4,682	29,13	0,016985	0,143565	0,002438
1997-5	1659	1856	4,883	30,08	0,016975	0,141619	0,002404
1997-6	1528	1664	4,599	32,20	0,017617	0,138810	0,002445
1997-7	1373	1587	4,786	32,39	0,018311	0,134562	0,002464
1997-8	1441	1707	5,406	30,41	0,018023	0,131086	0,002363
1997-9	1605	1711	5,605	28,10	0,017049	0,136692	0,002330

1997-10	1658	1752	5,281	27,98	0,016645	0,141337	0,002353
1997-11	1474	1495	4,831	27,72	0,016486	0,141756	0,002337
1997-12	1516	1498	4,877	26,51	0,016770	0,137929	0,002313
1998-1	1317	1448	4,821	25,78	0,016689	0,133556	0,002229
1998-2	1193	1318	4,796	27,80	0,016871	0,132370	0,002233
1998-3	1363	1304	4,736	26,21	0,016810	0,131973	0,002218
1998-4	1445	1386	5,009	25,05	0,016469	0,132869	0,002188
1998-5	1408	1466	4,987	25,28	0,016597	0,134335	0,002230
1998-6	1438	1452	5,628	24,41	0,016319	0,132074	0,002155
1998-7	1543	1649	5,945	27,56	0,016164	0,131185	0,002120
1998-8	1602	1555	6,889	28,01	0,016481	0,129683	0,002137
1998-9	1966	1664	7,598	31,80	0,015852	0,131977	0,002092
1998-10	2244	2526	7,601	36,43	0,015792	0,134624	0,002126
1998-11	2098	2248	7,295	36,80	0,016036	0,134214	0,002152
1998-12	2256	2319	8,418	36,96	0,015965	0,131775	0,002104
1999-1	2285	2379	7,476	34,36	0,015407	0,134185	0,002067
1999-2	2369	2421	6,830	34,02	0,015724	0,129554	0,002037
1999-3	2552	2624	7,348	34,84	0,016002	0,127928	0,002047
1999-4	2468	2641	7,275	33,87	0,016123	0,128631	0,002074
1999-5	2411	2539	7,382	33,09	0,016083	0,129011	0,002075
1999-6	2641	2670	9,275	37,24	0,015097	0,127063	0,001918
1999-7	2631	2843	6,145	39,34	0,015160	0,126528	0,001918
1999-8	2808	2729	5,464	42,23	0,015182	0,128357	0,001949
1999-9	2994	2821	5,453	44,22	0,014509	0,127631	0,001852
1999-10	2897	2791	5,362	43,65	0,014289	0,129164	0,001846
1999-11	2970	2958	5,183	44,41	0,014789	0,126207	0,001866
1999-12	2999	2966	5,579	44,73	0,015146	0,124828	0,001891
2000-1	2762	2676	5,299	42,74	0,016084	0,124799	0,002007
2000-2	2615	2523	4,734	43,48	0,016703	0,121417	0,002028
2000-3	2660	2423	4,953	44,38	0,016826	0,118891	0,002001
2000-4	2482	2348	4,796	45,81	0,017358	0,116170	0,002016
2000-5	2392	2459	4,425	46,28	0,016964	0,110533	0,001875
2000-6	2624	2483	5,426	44,33	0,015923	0,115223	0,001835
2000-7	2009	2527	4,187	41,49	0,015938	0,114911	0,001831
2000-8	2286	2558	4,269	40,38	0,016168	0,111662	0,001805
2000-9	2105	2860	4,490	39,93	0,016086	0,108630	0,001747
2000-10	1991	1726	4,336	36,97	0,016254	0,106823	0,001736
2000-11	1855	1781	4,296	34,68	0,016029	0,107102	0,001717
2000-12	1762	1781	4,484	31,52	0,015340	0,110300	0,001692

Table A2. Monthly fish meal prices and exchange rate from January 1994 to December 2001 (Sources: IFFO, Norges Bank, Banco Central de Reserva del Perú)

Date	FOB Peru (PEN per tonne)	C&F Hamburg (EUR per tonne)	PEN/EUR	Date	FOB Peru (PEN per tonne)	C&F Hamburg (EUR per tonne)	PEN/EUR
1994-01	730	329	2.428	1998-01	1812	647	2.985
1994-02	726	326	2.437	1998-02	1888	642	3.051
1994-03	545	308	2.477	1998-03	1911	628	3.052
1994-04	706	308	2.481	1998-04	1891	625	3.087
1994-05	712	311	2.548	1998-05	1893	617	3.162
1994-06	745	309	2.588	1998-06	1891	612	3.206
1994-07	766	308	2.684	1998-07	1853	600	3.215
1994-08	785	310	2.718	1998-08	1912	607	3.273

1994-09	832	318	2.784	1998-09	2004	588	3.527
1994-10	829	317	2.813	1998-10	1820	550	3.672
1994-11	814	318	2.722	1998-11	1495	514	3.618
1994-12	811	345	2.595	1998-12	1422	462	3.692
1995-01	852	351	2.711	1999-01	1439	441	3.766
1995-02	877	349	2.779	1999-02	1277	418	3.804
1995-03	893	343	2.943	1999-03	1024	387	3.678
1995-04	890	337	3.002	1999-04	974	334	3.581
1995-05	907	334	2.941	1999-05	969	315	3.538
1995-06	972	354	2.967	1999-06	1048	331	3.464
1995-07	1026	376	2.988	1999-07	1143	338	3.445
1995-08	1053	381	2.899	1999-08	1240	337	3.564
1995-09	1069	395	2.876	1999-09	1258	360	3.588
1995-10	1132	402	2.935	1999-10	1233	373	3.717
1995-11	1276	464	3.007	1999-11	1267	388	3.594
1995-12	1351	507	2.972	1999-12	1307	407	3.523
1996-01	1394	515	2.963	2000-01	1347	411	3.543
1996-02	1376	512	2.956	2000-02	1258	416	3.399
1996-03	1340	491	2.961	2000-03	1167	406	3.321
1996-04	1240	469	2.948	2000-04	1165	407	3.288
1996-05	1228	459	2.961	2000-05	1202	424	3.177
1996-06	1240	454	3.023	2000-06	1384	442	3.315
1996-07	1225	435	3.079	2000-07	1389	451	3.266
1996-08	1270	425	3.136	2000-08	1349	461	3.145
1996-09	1325	450	3.145	2000-09	1356	482	3.030
1996-10	1416	463	3.211	2000-10	1358	486	2.983
1996-11	1414	472	3.290	2000-11	1337	484	3.013
1996-12	1412	469	3.221	2000-12	1531	516	3.155
1997-01	1412	476	3.182	20001-01	1582	512	3.304
1997-02	1383	481	3.060	20001-02	1482	504	3.247
1997-03	1360	483	3.026	20001-03	1355	488	3.196
1997-04	1370	480	3.046	20001-04	1381	488	3.178
1997-05	1386	479	3.057	20001-05	1469	501	3.148
1997-06	1439	493	3.011	20001-06	1504	536	3.012
1997-07	1473	528	2.915	20001-07	1629	560	3.017
1997-08	1593	580	2.848	20001-08	1662	563	3.151
1997-09	1614	580	2.912	20001-09	1640	556	3.182
1997-10	1663	588	2.988	20001-10	1727	562	3.132
1997-11	1735	627	3.105	20001-11	1806	612	3.054
1997-12	1765	648	3.027	20001-12	1817	642	3.064

PAPER 4

Forecasting Commodity prices with switching regimes:

A MS-VAR approach for fish meal price

by

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Abstract: The objective of this paper is to present a parsimonious forecasting model of the fish meal price. The focus is on the soybean meal market's impact on the fish meal price together with the stocks-to-use as an indicator of demand and supply conditions. A salient feature of the fish meal market is the impact of El Niño events on fish meal supply. This possibly leads to two different price regimes, one where the fish meal price is highly correlated with the soybean meal price, and another, during El Niño events, where fish meal supply is low and the fish meal price is not strongly correlated with the soybean meal price. The results from the Markov-switching autoregressions indicate two price regimes where one is mostly governed by the soybean meal price while the other is governed by the level of stocks-to-use.

Keywords: Fish meal market, price regimes, Markov-switching autoregression.

1. Introduction

The main objective of this paper is to examine whether a Markov-switching vector autoregressive (MS-VAR) model improves modeling and forecasting of fish meal prices. Traditionally, autoregressive integrated moving average (ARIMA) and restricted vector autoregressive (VAR) models have showed the best forecasting performance in agricultural economics compared with more basic forecasting methods like naïve models, extrapolation, and other univariate models (Allen, 1994; Guttormsen, 1999). Commodity price movements have, however, certain built-in non-linear characteristics due to the nature of commodity markets, which might call for a non-linear approach like the MS-VAR model.

Reliable forecasts of commodity prices are an important tool for risk management. Not the least for salmon aquaculture, considering that feed costs account for over 50% of the variable costs, where fish meal together with fish oil are by far the largest feed inputs in terms of costs. A study by Guttormsen (2002) indicates that substitutability between feed and other inputs in salmon aquaculture is close to zero, further emphasizing the vulnerability of feed producers and fish farmers to changing raw material prices. Good forecasts are therefore important for making hedging decisions like ones suggested in earlier studies (Gjerde, 1989; Vukina and Anderson, 1993).

Commodity markets have a price floor by construction, as one does not observe negative prices. Consequently prices are able to spike upwards, but are limited in their downward movements, creating an asymmetry in price movements. Storage accentuates the asymmetric price pattern by being more effective at eliminating exceedingly low prices, by pulling out stocks from the market, than vice versa, since it is impossibility to carry negative inventories (Wright and Williams 1982). In other words, in periods with supply shortages stocks are usually depleted and thereby create higher and more volatile prices, while in periods with normal supply producers can stabilize prices by e.g. withholding stocks from the market when prices are getting undesirable low. The asymmetry of commodity price movements complicates accurate modeling and forecasting since it leaves linear estimation methods inappropriate in the sense that the underlying price mechanisms is not linear.

A MS-VAR model might alleviate these difficulties. Usually Markov switching models are reserved for financial and macroeconomic data dealing with issues like business cycles, core inflation, and interest rate volatility.[46] Yet, Markov switching models might also be called for in commodity markets with multiple price regimes since it potentially provides more accurate description of the price formation process and better forecasts. It is not obvious, however, that asymmetries in commodity prices are pronounced enough to justify such an approach, or for that matter best described as being a result of multiple price regimes. It is therefore important to consider whether a commodity market is plausibly described as having more than one price regime. A few studies suggest this is the case for the fish meal market (Tveterås and Tveterås, 2002; Asche and Tveterås, 2000).

More specifically these studies indicate that there is one regime where prices are high and demand is inelastic and another regime where prices are low and demand is more elastic. This implies a kinked demand curve for fish meal. Deaton and Laroque (1992) pointed out that a convex demand curve combined with large harvest variability leads to large variability in prices. Considering the highly volatile fish meal supply caused by large natural variations in the industrial fisheries this seems like a fitting description of the fish meal market. Even if the

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[46] The following references is only a small sample from the large literature on regime switching in financial and macroeconomic literature; Hamilton (1989, 1991); Perez-Quiros and Timmermann (2001); Smith (2002); Morana and Beltratti (2002); Clements and Krolzig (2002); Krolzig (2001).

demand curve for fish meal might be more appropriately described as kinked rather than convex the implications are still the same.

This paper is organized as follows. The next section gives background of the fish meal market with emphasis on the demand and supply characteristics. Section 3 presents the MS-VAR modeling approach. In Section 4 the data are presented followed by the empirical results in Section 5, and then finally conclusion in Section 6.

2. Background

The large variations in the industrial fisheries are caused by the El Niño weather phenomenon that takes place approximately every 3 to 7 years. This can cause shortages in supply that are unfamiliar even in agricultural production, as some of the worlds largest fisheries situated in the Pacific outside South America are near depleted due to the lack of nutritious surface water.[47] Other important characteristics of the industrial fisheries include natural variability in pelagic fish stocks and fishery management, which has not always been up to the task. All of these are important factors behind the supply fluctuations, which also translates into volatile fish meal prices. In particular, El Niño events have a negative impact on fish meal supply and thereby fish meal prices. For the end user, the compound feed producer, the variable fish meal supply translates into uncertainty and risk.

Salmon feed producers prefer fish meal as the main protein source because of the high nutritional value of marine proteins in terms of essential fatty and amino acids. However, marine proteins are also used in livestock feeds. Fish meal has been used in pig and poultry feeds for several decades already, preceding aquaculture's expansion, and there is even

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[47] Pelagic species used for fish meal production are free migrating fish species that inhabits the surface waters, as opposed to demersal fish species.

evidence of a kinked demand curve for fish meal before aquaculture became a player in this market (Hansen, 1980). The so-called Unidentified Growth Factor can be an explanatory factor in this respect. The term refers to the increased growth rate of animals associated with using fish meal instead of alternative protein sources in feeds for young animals. The growth of intensive aquaculture production has changed the consumption pattern of fish meal, because of its higher willingness to pay for marine proteins compared to the pig and poultry sector. Since the end of the 1990s aquaculture has been the largest consumer of fish meal.

There are alternative protein sources to fish meal for both fish and livestock feeds. Soybean meal is the most widely available with somewhat similar nutritional profile as fish meal. Empirical findings indicate that these two markets are strongly integrated, as prices tend to move proportionally over time (Asche and Tveterås, 2000). Fish meal prices still exhibit short-term deviations from soybean meal prices. Furthermore, the degree of substitutability between fish meal and alternative protein sources varies with the particular aquaculture and animal species, and substitution from one protein source to another is complicated by logistical and technical reasons. For example most producers have limited storage space available. This limits how much can by purchased of a certain feed input at any given time, even if relative prices favor substitution from one to the other feed ingredient. Another sluggishness in substitution is that animals and aquatic species needs time to adapt to new feeding regimes.

3. Methodology

In a competitive market prices are determined by demand and supply. The purpose of this study is not to develop a supply and demand system since it is too costly to attain data for such extensive models for other than on an annual basis. Instead I concentrate on leading indicators, which is commonly used in short-term financial and agricultural forecasting (Allen, 1994).

Time-series forecasting methods is constantly evolving with an array of modeling approaches to choose from, some more sophisticated than others. Unfortunately, forecasting performance is not improving at the same pace as forecasting techniques are developing. What can be perceived as somewhat disappointing forecasts has to be evaluated in view of an inherently uncertain future. How models handle the uncertainty is, nevertheless, crucial for forecasting performance. As Clements and Hendry (1996) note, shifts in deterministic components are one of the major reasons why forecasts break down, which can explain why naïve forecasts often 'win' over more advanced forecasting models. As naïve models do not contain any deterministic components they avoid forecast breakdowns associated with deterministic shifts. Still, there have been improvements in forecasting performance over the years. In particular, ARIMA and restricted VAR models have shown good performance. More recent models like switching models, generalized autoregressive conditional heteroscedacity (GARCH), autoregressive fractionally integrated moving average (ARFIMA) and other non-linear forecasting techniques have yet to prove their forecasting abilities.

The usual approach in VAR modeling is to treat parameters as fixed over time. In an MS-VAR model we alternatively let the parameters vary over time implying a non-linear data generating process. Hamilton (1989, 1990) developed a procedure for estimating regime shifts using a Markov chain to represent the regime generating process, which was further formalized with the MS-VAR framework by Krolzig (1997). There is a number of ways to restrict the MS-VAR model. This includes restricting parameters to be constant over regimes, either autoregressive or intercept parameters, like parameters in a regular VAR model.

The unrestricted parameters will change in accordance with regime changes. These changes are governed by an explicitly stated probability law and can be derived using the Expected Maximum likelihood (EM) algorithm. The purpose of this algorithm is to identify regime shifts, to estimate parameters associated with each regime, and characterize the probability law for transition between regimes. This is based on the state space form of the Kalman filter, but unlike the linear Kalman filter the EM algorithm is capable of nonlinear inference. It is also a numerical robust algorithm for maximizing sample likelihood. I use the MS-VAR package for OX for model estimation.

The general idea behind such Markov switching models is that the parameters of a K-dimensional time series process depend on an unobservable regime $s_t \in \{1,...,M\}$.

$$p(y_t \mid Y_{t-1,}X_t,s_t) = \begin{cases} f(y_t \mid Y_{t-1},X_t,\theta_1 & \text{if} \quad s_t = 1 \\ \vdots & \\ f(y_t \mid Y_{t-1},X_t,\theta_M & \text{if} \quad s_t = M \end{cases} \qquad (2)$$

where $Y_{t-1} = \{y_{t-j}\}_{j=0}^{\infty}$ denotes the history of y_t and X_t are exogenous variables. The θ_m is the VAR parameter vector associated with regime *m*. The regime generating process is an ergodic Markov chain with a finite number of states defined by the transition probabilities:

$$p_{ij} = \Pr(s_{t+j} = j \mid s_t = i), \qquad \sum_{j=1}^{M} p_{ij} = 1 \qquad \forall i,j \in \{1,..., M\} \qquad (3)$$

Thus, the conditional distribution of any future regime s_{t+1} given the past regimes $s_0, s_1, ..., s_{t-1}$ and present regime s_t is independent on past regimes and depends only on the present regime. The Markov-switching regression model is defined as

$$y_t = \begin{cases} X_t\beta_1 + u_t & u_t \mid s_t \sim NID(0, \Sigma_1) \text{ if } s_t = 1 \\ \vdots & \\ X_t\beta_M + u_t & u_t \mid s_t \sim NID(0, \Sigma_M) \text{ if } s_t = M \end{cases} \qquad (4)$$

The most general form of a Markov-switching vector autoregressive (MS-VAR) process is given by

$$y_t = v(s_t) + A_1(s_t)y_{t-1} + ... + A_p(s_t)y_{t-p} + u_t, \qquad u_t \mid s_t \sim NID(0, \Sigma(s_t)), \; (5)$$

where all the parameters $\theta = \{v, A_1, ..., A_p)$ are dependent on regime s_t, where s_t is a random variable that can assume only an integer value {1,2,…,N}. There are two components of a VAR model: 1) the Gaussian VAR model as the conditional data generating process, and 2) the Markov process as the regime generating process, i.e., the density of y_t is conditional on pre sample values Y_{t-1} and the different states s_t . The conditional density of y_t will be a mixture of normal distributions given that there is more than one state.

4. Data

Price data are collected from continental Europe, which is one of the biggest markets for fish meal. More precisely they are monthly averages of quoted prices for fair and average quality (FAQ) fish meal with 64/65 % protein contents delivered c&f Hamburg, Germany, while the soybean meal has 44/45 % protein content delivered from Argentina to Rotterdam cif. Fish meal Exporters Organisation (FEO) provides the data that are used for constructing the stocks-to-use indicator. Stocks-to-use, which is calculated by dividing carryover stocks with total use, is often used in agricultural price modeling as an indicator of demand and supply conditions. A low value indicates limited availability of stocks, which one would normally associate with higher prices. In this case it is constructed with production and inventory data from FEO, which represents some of the largest fish meal producing countries, namely Peru, Chile, Norway, Denmark and Iceland. These countries account for a large part of the global fish meal exports with e.g. approximately 82 % of the fish meal exports in 2000 (FAO, 2000).

The data are on a monthly basis and span from January 1988 to December 2001, as seen in Figure 1. These are the three variables used in the VAR and MS-VAR models.[48] Augmented Dickey Fuller tests indicate that the price series are I(1) process, as shown in Table 1, and are therefore differenced. The purposefulness of such differencing can be discussed in a forecasting context. Non-stationarity need not be a problem as such, since well-behaved residuals imply cointegration. However, in our case differenced data provide more robust models, and is therefore the preferred approach. All three variables are transformed to logarithms.

Table 1. Augmented Dickey-Fuller tests

Data series	*Test statistic, levels*	*Test statistic, first differences*
Fish meal price	-2.5427	-4.6513**
Soybean meal price	-1.9102	-5.9989**
Stocks-to-use	-3.2089	-7.6364**

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[48] The MS-VAR models are estimated using MSVAR package for OX created by Krolzig (1998).

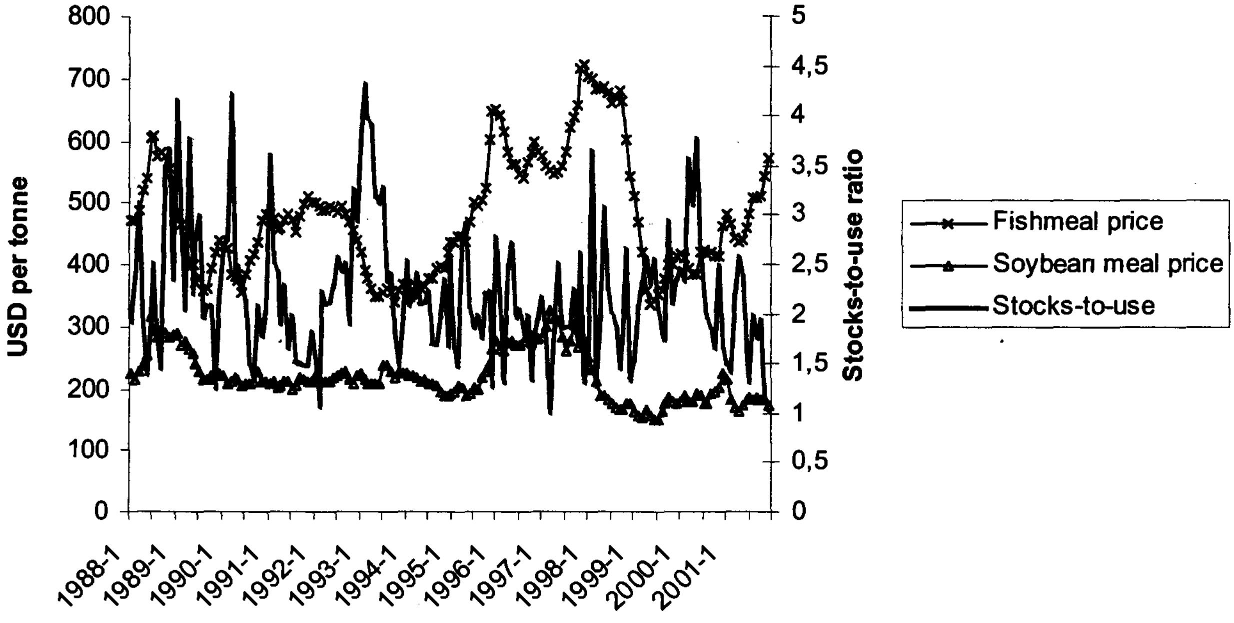

Figure 1. Monthly fish meal and soybean meal price data from Hamburg and Rotterdam together with a stocks-to-use indicator for fish meal (OilWorld; FEO).

5. Empirical Results

The VAR model is first estimated unrestricted with all the 3 variables as endogenous to avoid potential endogeneity problems. Two dummies are included in the VAR model in order to account for outliers. The model specification also contains a dummy for El Niño in 1997/98, which has been chosen based on Chow tests for structural breaks. Tests for Granger non-causality of whether soybean meal and stocks-to-use are Granger caused by any of the other two variables are not rejected with the respective Wald statistics of 2.8639 [0.8257] and 7.6285 [0.2666].[49] Following the VAR model is reduced to an AR model.

This leads to the two different models reported in Table 2; an AR(1) and a MS-AR(3) model. The AR(1) has two exogenous variables where only significant lags are included. In addition there are seasonal dummies and dummies for the two outliers. Lag length is based on specification tests. First, we notice that the both own lagged variable and the exogenous variables DlnSP (soybean meal price) and DlnS/U (stocks-to-use) have sensible signs; own

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[49] p-values in brackets.

price lag is positive, soybean meal price, which is a substitute, is positive, and, finally, stocks-to-use is negative.

Table 2. Parameter estimates of an AR model and a MS-AR model with two regimes

Variable	*AR(1)*	*MS(2)-AR(3) regime 1*	*MS(2)-AR(3) regime 2*
DlnFP_1	0.3102**	0.4269**	0.3099**
DlnFP_2		0.0956	-0.1604
DlnFP_3		0.3162*	-0.0116
DlnSP	0.2032**	-0.0880	0.3247**
DlnSP_1		0.0421	0.0010
DlnSP_2		0.0770	0.0386
DlnSP_3		0.0763	-0.0198
DlnS/U	-0.0315**	-0.0621**	-0.0098
DlnS/U_1	-0.0204	-0.0542**	-0.0046
DlnS/U_2	-0.0181	-0.0663**	0.0002
DlnS/U_3		-0.0510**	0.0228
Seasonal	-0.0032		
Seasonal_1	-0.0090		
Seasonal_2	-0.0240*		
Seasonal_3	-0.0042		
Seasonal_4	0.0048		
Seasonal_5	0.0158		
Seasonal_6	0.0137		
Seasonal_7	-0.0094		
Seasonal_8	0.0053		
Seasonal_9	0.0168		
Seasonal_10	0.0204*		
d9511	0.1042**		
d9810-9904	-0.0679**		

*indicates 5% significance level, while ** indicates 1% significance level

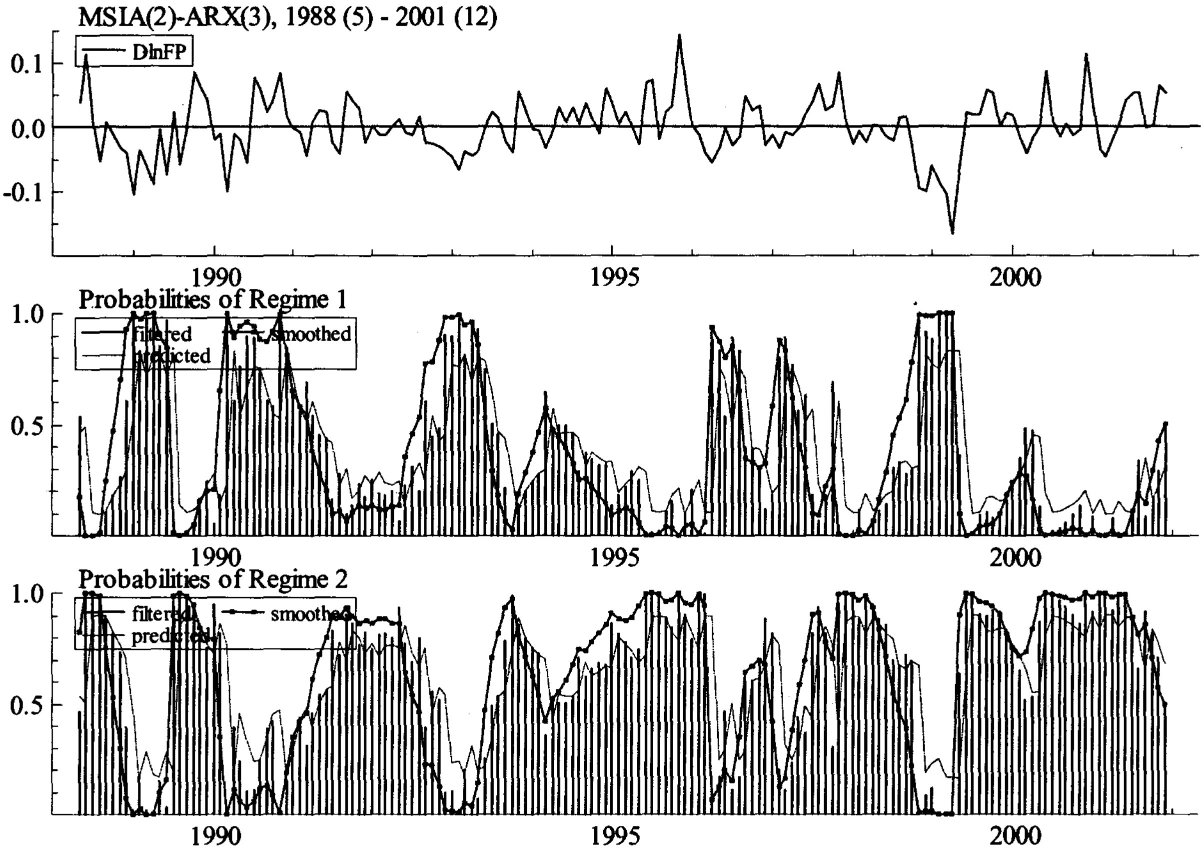

Figure 2. Plot of DlnFP and the probability distributions of regime 1 and 2 occurring from the MS-AR(2) model

Next the specification of the MS-AR model is based on Aikake criterion and similar criteria. In the end a model with two regimes and three lags is chosen, with the estimated parameters as shown in Table 1. The results are interesting as they provide evidence of the two price regimes. In regime one, which is the least prevailing in the estimated sample, all the soybean meal price coefficients are insignificant, while all the stocks-to-use variables are significant. While in regime 2 only soybean meal prices are signinficant except for the own price lag. This indicate that in regime 1 there is a detachment of the fish meal market from the soybean meal market where the price of fish meal is mainly determined by the supply of fish meal, while in regime two the soybean meal price is the price leader.

When it comes to forecasting the AR model outperform the MS-AR model based on Mean Sqaured Predicted Error (MSPE). From Table 3 we see the AR model has lower MSPE, with

0.0077 against 0.0128 of the MS-AR model. However, both the AR and MS-AR perform better than a NAÏVE model. In Figure 3 the forecasts from the Naïve, AR, and MS-AR model are plotted against the actual values of DlnFP. The fact that the own-price lag is just as significant in the MS-AR model as in the AR model is probably an indicator that the forecasting abilities are not superior of the AR.

Table 3. Mean Squared Predicted Error

Data series	*MSPE*
MS-AR	0.0128
AR	0.0077
NAIVE	0.0209

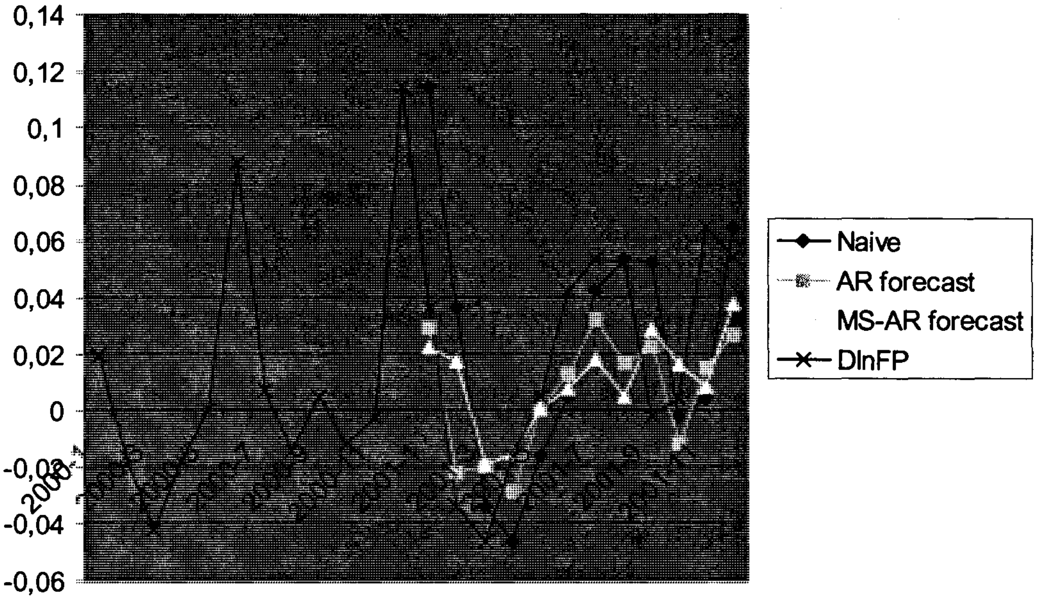

Figure 3. One step ahead within sample forecasts of the differenced fish meal price based on Naïve, AR, and MS-AR model

6. Concluding remarks

This paper compares modeling and forecasting of a fish meal price using both VAR and MS-VAR models. The motivation for introducing a Markov switching model for the fish meal price is both as a means for more accurate modeling of the fish meal price and for producing better forecasts. There is empirical evidence of more than one price regimes in the fish meal market. Furthermore, economic theory of storage supports the notion that commodity price movements are non-linear, which in the case of the fish meal market seems to provide a good description. The severe impact of El Niño on fish meal production makes the fish meal market somewhat unique by inducing shortfalls in the supply that are not often observed in other markets. In these periods fish meal stocks run low, which makes the fish meal price very sensitive to supply changes.

Two leading indicators have been chosen for explaining the fish meal price, the soybean meal price and stocks-to-use. Initially an unrestricted VAR models is estimated, i.e., as a system with three endogenous variables. As both the soybean meal price and stocks-to-use are found to not be Granger caused by any of the other two variables, the VAR and MS-VAR models reduced to single equation models with the fish meal price as the left-hand side variable. Model wise, the results of the MS-VAR model are encouraging in the sense that they seem to give a plausible account of the underlying price mechanism. The results indicate the in periods the fish meal market decouples from the soybean market when supply gets tighter, and subsequently stocks-to-use gets more important in explaining the fish meal price. This is in accordance with what we should expect with a kinked demand curve for fish meal. Forecasting performance of the MS-VAR is, however, not so convincing relative to regular VAR model. It is a known fact that in sample fit is no guarantee for good forecasting performance, and this seems to be such a case.

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PAPER 5

Fish Meal Demand from Livestock and Aquaculture:

Inference Using a Shrinkage Estimator for Panel Data

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Abstract: There are few studies using heterogeneous shrinkage estimators for panel data analyses, and existing ones differ in their view regarding the performance of shrinkage estimators relative to standard pooled and single equation estimators for panel data. Our focus is on inference, where we estimate a panel data model of derived demand for fish meal using a shrinkage estimator for major fish meal importing countries. The derived demand model estimated by OLS produces implausible elasticities for some countries, while shrinkage estimates are generally reasonable. According to standard asymptotic tests the precision of predictions is substantially higher for a shrinkage estimator than for the OLS country-specific estimates and pooled estimators. When the theoretically more appealing bootstrap method is used for inference, confidence intervals become much wider. Bootstrap confidence intervals generally fail to provide statistical support for the sign of the shrinkage elasticity estimates, although OLS estimates suffer even more in this process. According to the empirical results from the shrinkage model fish meal demand is in general inelastic in own price and highly inelastic in salmon output, leading to a somewhat mixed picture with respect to the effects of growth in salmon production.

Keywords: Shrinkage estimator, pooled estimators, panel data, bootstrap, fish meal, demand, livestock and aquaculture feeds.

1. INTRODUCTION

Few degrees of freedom is a recurrent problem in demand analysis, and is closely related to the debate of whether to pool data (see e.g. Maddala, 1991; Maddala et al. 1997; Pesaran and Smith, 1995; Baltagi and Griffin, 1997; Baltagi, Griffien, and Xiong, 2000). Pooling provides more degrees of freedom, but lead to a loss of information by imposing homogeneity across individuals. This is the crux of the discussion, which, with the danger of oversimplification, can be stated as whether to sacrifice more information for firmer statistical support. A route that allows one to obtain estimates that retain heterogeneity across individuals, while still exploiting information from the entire panel, is to use a so-called shrinkage estimator (Maddala *et al.*, 1997). The estimator "shrinks" specific OLS parameter estimates of the individuals toward a common probability distribution, but differences between the individual estimates remain after shrinkage unless the initial OLS estimates are very similar.

One central objective of this study is to examine the small-sample properties of the shrinkage estimator for panel data proposed in Maddala *et al.* (1997). Earlier studies have shown that shrinkage estimators can produce more reasonable estimates than individual OLS estimates on each country when there is a small number of observations (Maddala *et al.*, 1997; Baltagi and Griffin, 1997; Baltagi, Griffin and Xiong, 2000). Still, some maintain that pooled-data estimators provide more plausible estimates (Baltagi and Griffin, 1997; Baltagi, Griffin and Xiong, 2000). One way of evaluating estimators is by comparing the plausibility of their results, which is in line with earlier studies. In our empirical application on the international fish meal market, we compare long-run demand elasticities obtained from the shrinkage estimator with those obtained from pooled and individual least-square estimators.

Inference is however a problem with the shrinkage estimator since the sampling distribution is more tightly concentrated than for least squares. As a result standard asymptotic theory is not useful (Kazimi and Brownstone, 1999), something which has not been properly addressed in earlier studies. Maddala *et al.* (1997) did not report *t*-values for the estimated demand elasticities, as opposed to Baltagi and Griffin (1997) and Baltagi, Griffin, and Xiong (2000). However, the latter two studies did not specify the method that they used for constructing such *t*-values. It is likely they used an analytical method like the Fieller's method or the delta method (i.e., Taylor series approximation), both of which rely on normally distributed errors. The use of standard distributions leaves one questioning the validity of such results. Bootstrapping is a possible remedy to nonstandard distributions, as it can be used to construct a consistent estimate of the underlying population distribution. We consider bootstrap methods for constructing appropriate confidence intervals for the estimated demand elasticities.

In addition to examine the small-sample properties of the shrinkage estimator for panel data, the alternative methodologies will be used to obtain more knowledge about the structure of fish meal demand. In our econometric analysis of fish meal demand a panel of 12 countries are used, five that demand fish meal both for terrestrial livestock production and intensive aquaculture, and seven that demand fish meal mainly for terrestrial livestock production. Potential structural differences between these countries make it desirable to obtain country-specific estimates of demand elasticities. Factors such as national tariff and subsidy schemes, technological characteristics of production, and composition of meat production can lead to heterogeneous demand structure across countries.

Fish meal is an important ingredient in feeds for pigs, poultry and aquaculture. Stagnating industrial fisheries together with increasing human consumption of animal proteins have however led to a growing scarcity of fish meal (Delgado, Crosson and Courbois, 1997). There is particular concern about the rapid growth of carnivorous aquaculture species like salmon and shrimp, which, according to some researchers and policy makers, will cause increased pressure on wild fish stocks and higher fish meal prices (Naylor *et al.*, 2000). We seek to answer whether increased livestock and aquaculture production will in fact put pressure on the fish meal market. Long-run trends in fish meal demand are crucial for the continued price development, as there is limited scope for increase in fish meal supply with catches of wild fish species fit for reduction having reached or even surpassed sustainable levels. A better understanding of demand for marine proteins will improve our ability to predict how increasing fish meal scarcity influence prices and the future growth of certain livestock and aquaculture production sectors.

In the next section we outline some important features of the fish meal market relating to the structure of demand and supply. Then, in Section 3, we proceed with describing the shrinkage estimator we will use for estimating fish meal demand, together with a short description of bootstrap methods for obtaining relevant distributions, which are employed for drawing inference from the results. Section 4 gives a short presentation of the data, followed with the model specification in Section 5, and then results from the estimations of the fish meal demand model. Finally, in Section 7 summary and conclusion.

2. BACKGROUND

Figure 1 shows the rapid growth of global aquaculture, and also the steady increase in pig and poultry production during the last decades. From 1985 to 2000 the annual average increases in pig and poultry production were 2.2 % and 3.6 %, while in the same fifteen-year period intensive aquaculture production has experienced a 5.5 % annual growth. Such trends reflect the global increase in human consumption of pig, poultry and fish, and continued growth implies an increased demand for protein inputs for feeds, among them fish meal.

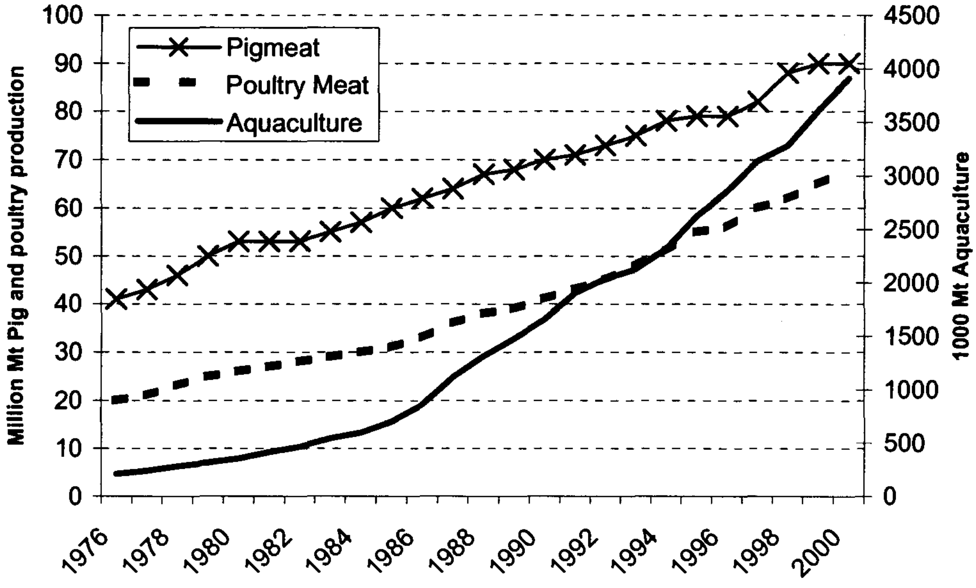

Figure 1. Global pig, poultry and intensive aquaculture production (Source: FAO databases FAOSTAT Agriculture and FISHSTAT)[50]

The main bulk of the global fish meal production is concentrated among a handful of countries. With the world's largest industrial fisheries situated in the Southeast Pacific, Peru and Chile account for over 50 % of global output. The Nordic countries, Iceland, Norway, and Denmark, come in as the second most important group of fish meal producers. Since catches of most of the industrial fish stocks are stagnating, long-run supply can be viewed as stochastic around a stationary mean of approximately 6-7 million metric tons, as can be seen

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[50] The aquaculture aggregate is based on the major intensive aquaculture species, which includes salmonids, shrimps and prawns together with tilapia and other cichlids. Intensive aquaculture can be characterised by high concentrations of fish in small enclosures, where the nutritional requirements are satisfied by manufactured compound feeds which usually includes fish meal as an ingredient.

from Figure 2 (FAO, 2000). Supply can vary considerably from year-to-year, primarily due to the El Niño weather phenomenon, but also caused by shifts in fisheries regulations.[51] Note the impact of the 1997/1998 El Niño in Figure 2 with the reduced output in 1998.

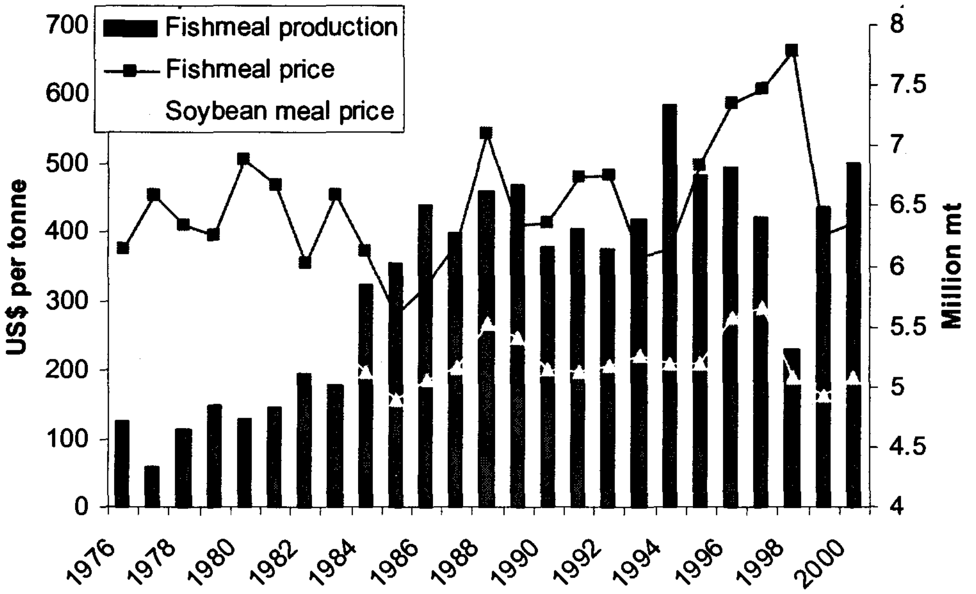

Figure 2. Global Fish meal Production and Hamburg Fish meal and Soybean Meal Prices (Sources: *FAO* and *Oil World*)

Market integration studies tie the fish meal market to the larger vegetable oilmeal market, which is not surprising since fish meal and vegetable oilmeals are used as alternative protein sources for animal and aquaculture feeds (Vukina and Anderson 1993; Asche and Tveterås 2000). This indicates the fish meal price is determined by the prices of substitutes like soybean meal, since the fish meal market is relative small compared to that of soybean meal. However, specific quality attributes of fish meal suggest this is only partly true. In particular, the aquaculture sector prefers marine proteins to vegetable proteins because the nutritional structure of fish meal better reflect the feed requirements of carnivore aquaculture species.

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[51] The El Niño southern oscillation refers to the occurrences of unusal warm sea-surface temperature in the Southern hemisphere of the Pacific, which suppresses the upwelling of nutritious cold water, thereby having a devastating effect on pelagic fisheries.

Fish meal also makes for a valued protein input in the feeds of simple-stomached animals due to its favourable balance of amino acids, its vitamin B-content, and its positive effect on growth, particularly in the early stages (FAO, 1983). Both of these factors can contribute to a partial segmentation of fish meal with the vegetable meals markets.

Nonetheless, similar price movements points to a strong relationship between these markets, as we can see from figure 2. The Hamburg prices for fish meal reported in figure 2 are traditionally the most quoted fish meal prices, and have generally been regarded as representative of world market prices. The price ratio between fish meal and soybean meal has however increased over time, implying the relative scarcity of fish meal has increased. In the 1980s the average fish meal:soybean meal price ratio was 1.83, while it increased to 2.28 in the 1990s, with a maximum of 3.48 in 1998 due to El Niño.

One notable change in the fish meal industry that has taken place during the last two decades, is a shift towards producing more high-quality fish meals. Aquaculture's preference for high-quality fish meals has most likely been an important factor behind such product development, contributing to an increase in the average prices of marine proteins. Fish meal price increases have led many pig and poultry producers to substitute fish meal for alternative vegetable protein sources like soybean meal. El Niño in 1997/1998, with its devasting impact on the supply of marine proteins accelerated the use of alternative vegetable proteins due to unusually high fish meal prices. The substitution of fish meal with vegetable proteins is reflected with the changing consumption pattern of fish meal. While poultry, pig and aquaculture producing sectors consumed 60%, 20% and 10% respectively of the global fish meal supply in 1988, there have been radical changes later, as shown in Figure 3. In 2000, the poultry sector's share of fish meal consumption was more than halved compared to 1988, while the pork sector had increased its share to 29%. For aquaculture this period entailed more than a trebling of its consumption of fish meal, with a 35% consumption share of global consumption in 2000.

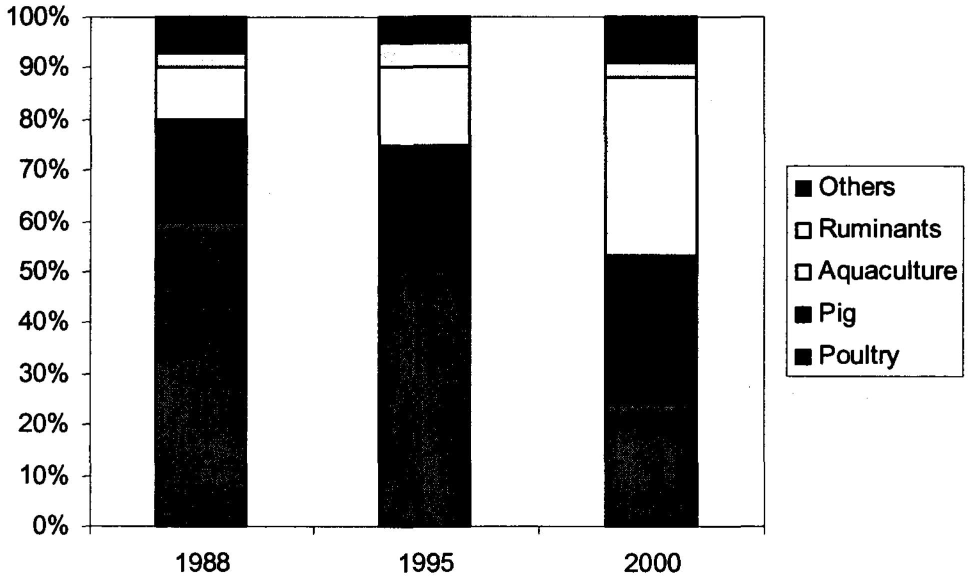

Figure 3. Share of fish meal used in different livestock and aquaculture feeds 1996 and 2000 (*Source: IFFO*)

In aquaculture, farmed salmon and shrimp are the largest consumers of fish meal with 45 % and 35 % of the feed consists of marine proteins respectively (Naylor *et al.*, 2000).[52] In contrast, the inclusion rates for fish meal in pigs and poultry feeds are much lower with a variation between 0-10 percent. Although fish meal feed inclusion rates might lead one to believe otherwise, terrestrial livestock still use a large share of marine proteins. This is not surprising as aquaculture production is small compared with pig and poultry production.

3. ESTIMATORS FOR FISH MEAL DEMAND

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[52] These figures are from 1997 and should be interpreted as approximate. Most likely average inclusion rates are lower today because of higher fish meal prices and more flexible feed technology (Tveterås, 2002).

Estimation of separate demand models for each country gives the greatest degree of flexibility with respect to elasticity estimates. But earlier studies have demonstrated that such regression models often provide implausible elasticity estimates, for example, positive own-price elasticities (Atkinson & Manning, 1995). Here, we compare eight different estimators, six on the pooled data set: (i) OLS, (ii) generalised least squares with a first-order autoregressive error term (GLS-AR1), (iii) two-stage least-square estimates (2SLS), (iv) fixed effects (FE), (v) random effects (RE), and (vi) a random effects model with a first-order autoregressive error term (RE-AR1). Finally, there are two heterogeneous estimators with (vii) separate OLS on each country and (viii) "shrinkage" estimation, which will be presented below. The estimator (i)-(vi) restricts all slope coefficients to be equal across countries, but where estimators (iv)-(vi) allows for a country specific intercept. (vii) and (viii) also allow for heterogenous slopes.

The "shrinkage" estimator shrinks estimates from separate regression models towards a population average. Although the shrinkage estimator allows for slope coefficient heterogeneity, it imposes some additional structure on the generation of the true coefficient values compared to separate OLS regressions on each country (Maddala *et al.*, 1997). This additional structure is the assumption of a common probability distribution, involving a common mean μ and non-zero covariance matrix Σ, from which the true parameter values of the demand models are drawn for each country. The coefficients estimated by the shrinkage method will be a weighted average of the overall pooled estimate and separate estimates from each country.

In its most general form the linear demand model, which is a random coefficients model, is specified as

(4) $y_i = X_i\beta_i + u_i, \qquad i = 1, 2, \ldots, N,$

where y_i is a $T{\times}1$ vector, X_i is a $T{\times}k$ matrix of observations on the k explanatory variables, β_i is a $k{\times}1$ vector of parameters, and u_i is a $T{\times}1$ vector of random errors which is distributed as $u_i \sim N(0, \sigma_i^2 I)$.

We assume that

(5) $\beta_i \sim IN(\mu,\Sigma)$,

or equivalently that

(6) $\beta_i = \mu + v_i$,

where $v_i \sim N(0,\Sigma)$. Equation (5) specifies the prior distribution of β_i in the Bayesian framework. The variance-covariance matrix Σ measures heterogeneity. From equations (5) and (6) we see the posterior distribution of β_i depends on μ and Σ. If μ and Σ are not known, priors must be specified. When μ, σ_i^2 and Σ, our parameters of interest so to speak, are known the posterior distribution of β_i is normal with mean and variance given by

(7) $$\beta_i^* = \left(\frac{1}{\sigma_i^2}X_i'X_i + \Sigma^{-1}\right)^{-1}\left(\frac{1}{\sigma_i^2}X_i'X_i\hat{\beta}_i + \Sigma^{-1}\mu\right),$$

(8) $$V(\beta_i^*) = \left(\frac{1}{\sigma_i^2}X_i'X_i + \Sigma^{-1}\right)^{-1},$$

respectively. $\hat{\beta}_i$ is the OLS estimate of β_i.

If the matrix X_i includes lagged values of y_i, the normality of the posterior distribution of β_i^* holds only asymptotically and under the usual regularity conditions assumed in dynamic regression models.

In the empirical Bayes approach that we employ, we use the following sample-based estimates of the parameters of interest, μ, σ_i^2 and Σ in equation (7):

(9a) $$\mu^* = \frac{1}{N}\sum_{i=1}^{N}\beta_i^*$$

(9b) $$\sigma_i^2 = \frac{1}{T-k}\left(y_i - X_i\beta_i^*\right)'\left(y_i - X_i\beta_i^*\right)$$

(9c) $$\Sigma^* = \frac{1}{N-1}\sum_{i=1}^{N}\left(\beta_i^* - \mu^*\right)\left(\beta_i^* - \mu^*\right)'.$$

We see that the prior mean μ^* is an average of the β_i^*, the estimate of the prior variance Σ^* is obtained from deviations of β_i^* from their average μ^*, and the estimate of σ_i^2 is obtained from the residual sum of squares using β_i^*, not the OLS estimator $\hat{\beta}_i$.

The equations (9) are estimated iteratively. In the initial iteration the OLS estimator $\hat{\beta}_i$ is used to compute μ^*, σ_i^2 and Σ^*. To improve convergence and to allow for adjustment of the weight of the individual units i in the estimation, (9c) is modified as

(9c') $$\Sigma^* = \frac{1}{N-1}\left[R + \sum_{i=1}^{N} w_i\left(\beta_i^* - \mu\right)\left(\beta_i^* - \mu\right)'\right],$$

where R is a diagonal kxk matrix with small values along the diagonal (e.g. 0.001), and w_i is a weight which determines the influence of unit i in the estimation of Σ^* ($\Sigma_i w_i = N$) According to a Monte-Carlo study by Hu and Maddala (1994), the iterative procedure gives better estimates in the mean squared sense for both the overall mean μ and the heterogeneity matrix Σ than two-step procedures.

Unfortunately, confidence intervals for demand elasticities may not be estimated by conventional analytical methods, such as Fieller's method and the delta method (i.e. Taylor series approximation), with the chosen model specification and estimator, because conventional methods rely on asymptotics, normal (or symmetric) distributions and exogenous regressors (Li and Maddala, 1999). Under these circumstances bootstrap methods represent an alternative for constructing appropriate confidence intervals. There are several bootstrap methods (Kazimi and Brownstone, 1999). Here, we use a nonparametric residual bootstrap where residuals $\hat{u} = y - X\hat{\beta}$ are estimated by OLS, and then these residuals $\hat{u}$ are randomly drawn with replacement to create 500 bootstrap sample vectors u_j^* ($j = 1, \ldots, 500$) with an equal number of elements NT. We sample an equal number of observations T of $\hat{u}$ with replacement from each country subsample i. For each sample the pseudo-y vector $y^* = X\hat{\beta} + u^*$ is formed, and the shrinkage estimator is used to estimate parameters β^* and the demand elasticities. Finally, bootstrap estimates of the elasticities are sorted in an ascending order, and then a 90% bootstrap confidence interval can be created by picking the lower and upper 5% and 95% percentiles of the sorted distribution.

4. DATA

In order to estimate derived demand for fish meal we use data from twelve large fish meal-consuming countries: Canada, Chile, Denmark, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, UK, and USA. All of the aforementioned countries have industrialised pig and poultry production, but only Canada, Chile, Ireland, Norway, and UK have sizeable intensive salmon production.[53] The term 'Non-salmon' producing countries is a simplification since some of the countries produce small quantities of salmon. However, these quantities are

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[53] China is the world's largest fish meal importer, and as such would have been desirable to include in the data set, but China has been omitted due to poor quality of data.

miniscule compared to the production of pig and poultry. We estimate pooled demand models separately for the seven 'non-salmon' countries and the five 'salmon' countries.

The data panel is comprised of annual data from the UN Food and Agriculture Organization (FAO) from 1975 to 1999. With 25 annual observations from 5 and 7 countries in the two data sets, 125 and 175 observations, respectively, are available for estimations from each data set. Prices of fish meal and the other feed inputs are unit values based on the country specific trade data. Next, fish meal consumption is defined as production + (imports – exports) + (initial stocks – ending stock).[54] Some unreasonable figures related to early years in fish meal consumption for Chile and Norway lead us to believe that there is some measurement errors associated with fish meal consumption construct for these two countries. This is particularly the case for Chile, and will be dealt with in the econometric estimation by smoothing a few observations early in the sample.

Given the large number of ingredients used in salmon, pig and poultry feeds, a certain level of aggregation is inevitable. The list of feed inputs is very long and inclusion of all of them is not feasible, as it would lead to multicollinearity issues and insufficient degrees of freedom. The studies of Peeters and Surry (1993) and Peeters (1995) provide a departure point for aggregating demand for feed ingredients, and lead us to the inclusion of three general categories of feed inputs, which are protein meals, vegetable oils and cereals.

5. EMPIRICAL MODEL SPECIFICATION

The general specification of the fish meal demand model is

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[54] Stock data are only included for the major fish meal producers Norway and Chile with data from International Fish meal and Fish oil Organization (IFFO).

(1) $X_{FM} = (W_{FM}, W_C, W_{SO}, W_{SM}, Y_{PP}, Y_S, T)$,

where X is quantity demanded, W denotes prices (unit values), Y is sectoral production, T is a time trend variable representing technical change, and subscripts FM = fish meal, C = cereals, SO = soybean oil, SM = soybean meal, PP = pig and poultry sector, and S = salmon sector. Cereals and soybean oil are first and foremost used as energy sources in feeds, although cereals also provide some proteins, while soybean meal are mainly used for their protein content like fish meal. The reasons why we have chosen soybean meal and soybean oil prices as leading indicators for vegetable meal and oil prices are twofold. First, since soybean products like meal and oil are generally more traded than similar vegetable oilseed products, they represent a more consistent choice across countries. Second, both of them have dominant positions in their respective markets, which make them natural candidates as leading indicators. For the cereal price an aggregate is constructed, as there is not such an obvious candidate for a leading indicator in this instance. The cereal price construct is based on weighted prices of maize, barley, wheat and other cereals.

Since the growth rates for pig and poultry production are highly correlated it is difficult to separate their impact on the fish meal market. It is therefore assumed that the pig and poultry production can be represented as an aggregated meat-producing sector, Y_{PP}. The assumption should not be too severe as both the pig and poultry sectors have least-cost based feed formulations with several alternatives to fish meal and similar feeding technologies.

The model specification implies that we are estimating the aggregate demand of a cost-minimizing multi-output sector producing pig and poultry and salmon. The technology is assumed to be nonjoint so that the cost of producing all outputs can be expressed as the sum of independent cost functions for each output, i.e.,

$$C(W_{FM}, W_C, W_{SO}, W_{SM}, Y_{PP}, Y_S) = C^{PP}(W_{FM}, W_C, W_{SO}, W_{SM}, Y_{PP}, Z) + C^S(W_{FM}, W_C, W_{SO}, W_{SM}, Y_S, Z)$$

where Z is a vector of variables that allows for shifts in the production function. As is usual in derived demand, output together with input prices are demand shifters.

As noted in the data section, disaggregated data of fish meal demand from pig, poultry and aquaculture sectors are not available, which would be desirable since it would allow us to estimate the sector specific demand directly. Without sector-specific data there is a separability issue, since it is not possible to observe what amount of fish meal goes to either of the two sectors. It implies that we cannot identify the sector-specific production functions for meat and salmon, $Y_{PP} = f_{PP}(X_{FM}, X_C, X_{SO}, X_{SM}, Z)$ and $Y_S = f_S(X_{FM}, X_C, X_{SO}, X_{SM}, Z)$, which constitute the basis for estimating derived demand elasticities for the individual sectors. One way to circumvent the separation problem is by estimating fish meal demand from countries that do not have any significant salmon production separately, as their demand is then representative of the meat producing sector. This is the strategy pursued here, where we have constructed two separate data sets as described above, one for salmon producing countries and another for non-salmon producing countries.

The econometric specification of the model of aggregate fish meal demand is given by the following log-log model:

$$\begin{aligned} \ln X_{FM,i,t} = {} & \alpha_{0,i} + \alpha_{X,i}\ln X_{FM,i,t\text{-}1} + \alpha_{FM,i}\ln W_{FM,i,t} + \alpha_{C,i}\ln W_{C,i,t} + \alpha_{CS,i}\ln W_{SO,i,t} \\ & + \alpha_{SM,i}\ln W_{OS,i,t} + \alpha_{YPP,i}\ln Y_{PP,i,t} + \alpha_{YS,i}\ln Y_{S,i,t} + \alpha_{T,i}t, \end{aligned} \tag{2}$$

where subscripts t (= 1977, 1978, . . . , 2000) denotes time, and i (={Canada, Chile, Denmark, Germany, France, Ireland, Italy, Japan, Netherlands, Norway, UK, USA}) denotes country. Note that the parameter vector α_i is allowed to be country-specific, as implied by the subscript i. The own-price elasticity of fish meal demand in country i is $e^{SR}_{FM,i} = \partial \ln X_{FM,i,t} / \partial \ln W_{FM,i,t} = \alpha_{FM,i}$ in the short run, where superscript SR represents short run, and $e^{LR}_{FM,i} = \alpha_{FM,i}/(1 - \alpha_{X,i})$ is the long-run own-price elasticity. The term involving salmon production, $\alpha_{YS,i} \ln Y_{S,i,t}$, is dropped from the estimation of the seven non-salmon producing countries.

If demand elasticities are different between the pig and poultry and salmon sectors, the estimated country-specific elasticities will be influenced by the relative size of pig and poultry production to salmon production. For example, if own-price elasticity of fish meal demand is lower in the salmon sector than in the pig and poultry sector, then the 'average' elasticity will decline as salmon production increases relative to pig and poultry.

6. EMPIRICAL RESULTS

6.1 Comparison of Pooled and Heterogeneous Estimates

In the empirical estimations we will focus on long-run demand elasticities for fish meal. Before we proceed to the country-specific fish meal-demand elasticities for OLS and shrinkage estimators, we compare results from the pooled and heterogeneous estimators. Table 1 contains long-run elasticity estimates for the fish meal demand model, with the sample of the five salmon producing countries, using several pooled and heterogeneous estimators. The long-run demand elasticities provided by the pooled estimators give a mixed and not so promising picture. Not only are none of the elasticities significant, many of them do also not seem plausible. The four uppermost pooled estimators, OLS, GLS-AR1, 2SLS and RE, have high own-price elasticities, ε_{WFM}, and cross-price elasticities, ε_{WSM} and ε_{WC}, contrasting the pooled fixed effect model, which has the "wrong" sign for the own-price elasticity and low values for the cross-price elasticities. With the pooled estimator at the bottom, the random-effects autoregressive model, fish meal demand is again elastic with own-price elasticity of 1.298, but not as strongly as the four uppermost pooled estimators. Pig and poultry output elasticity (ε_{YPP}) has, contrary to *a priori* expectations, a negative effect on demand for four of the six pooled estimators while salmon output elasticity, ε_{YS}, has a positive, but small effect on fish meal demand.

Table 1. Estimates of long-run elasticities for fish meal demand in 5 salmon producing countries.†

	Estimator	ε_{WFM}	ε_{WSM}	ε_{WC}	ε_{WSO}	ε_{YPP}	ε_{YS}
Pooled	**OLS**	-2.353 (-0.975)	1.849 (0.539)	-1.410 (-0.785)	-0.840 (-0.329)	-0.061 (-0.138)	0.181 (0.586)
	GLS-AR1	-4.182 (-1.890)	2.692 (0.639)	-2.233 (-1.116)	0.186 (0.059)	-0.186 (-0.340)	0.212 (0.606)
	2SLS	-3.940	3.392	-0.946 (-1.229)	0.562 (0.448)	0.184 (1.048)	0.275
	RE	-2.353 (-0.975)	1.849 (0.539)	-1.410 (-0.785)	-0.840 (-0.329)	-0.061 (-0.138)	0.181 (0.586)
	FE	0.040 (0.074)	0.367 (0.559)	-0.143 (-0.268)	-0.007 (-0.017)	-0.331 (-0.586)	0.045 (0.368)
	RE-AR1	-1.298 (-0.659)	1.335 (0.536)	-0.879 (-0.599)	-1.032 (-0.566)	0.031 (0.092)	0.174 (0.698)
Country Specific	**OLS min.**	-1.300	-0.012	-0.455	-0.461	-5.172	-0.027
	OLS average	-0.426	0.336	0.298	0.576	-0.690	0.167
	OLS max.	0.452	1.200	0.866	2.492	1.119	0.615
	Shrinkage min.	-0.212	0.459	0.092	0.139	0.211	0.083
	Shrinkage average	-0.199	0.498	0.119	0.163	0.268	0.096
	Shrinkage max.	-0.187	0.533	0.144	0.186	0.318	0.113

† *t*-values in parentheses, calculated by the delta method. It is not meaningful to report average *t*-values for the average country-specific shrinkage and OLS estimates.

Next, we consider the heterogeneous estimators. The OLS average corresponds to the approach advocated by Pesaran and Smith (1995). They argue that an average of the individual country regressions lead to consistent estimates of the parameters as long as N and T tend to infinity. Ours is not exactly a limiting case with a panel of only five countries, but the average is nevertheless included as it represents an alternative to the shrinkage and pooled estimators. Like the pooled estimators, the demand elasticities of OLS averages are not statistically significant. The elasticities are generally smaller than the pooled estimators, except for the pooled FE estimator. According to the OLS averages, fish meal demand is inelastic in own-price, with an average elasticity of –0.426. Furthermore, the cross-price elasticities are relative low (i.e. close to zero) together with the output elasticities for meat and salmon production.

The shrinkage estimator is the only one to produce significant demand elasticities.[55] The own-price elasticity of –0.199 suggests that fish meal demand is very inelastic in countries with intensive salmon production. As expected, soybean meal is the strongest substitute with a cross-price elasticity of 0.498. However, that pig and poultry production has higher output elasticity than salmon production is surprising.

Next, we investigate the results from the seven non-salmon producing countries reported in Table 2, which represent a benchmark for the estimates from the salmon producing countries. Overall the long-run elasticities for fish meal demand are considerably larger, often implausibly large, for the non-salmon producing countries than the salmon producing countries. This concurs with our expectations, as it is widely held that it is technically more difficult to substitute away fish meal in salmon feeds than in pig and poultry feeds. Another difference compared to the results from the non-salmon producing countries is that many more elasticities are significant, including all own-price elasticities. However, the same pattern appears between the relative sizes of the demand elasticities from the different estimators. The pooled OLS, GLS-AR1, 2SLS, RE, and RE-AR1 have the highest point

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[55] See Table 3 for t-values of the country-specific elasticities for the salmon producing countries.

estimates, while the pooled FE together with the average OLS and shrinkage point estimates are the lower ones. Besides the FE model the elasticities of the pooled estimators seem implausibly high.

Table 2. Estimates of long-run elasticities for fish meal demand in 7 non-salmon producing countries.†

	Estimator	ε_{WFM}	ε_{WSM}	ε_{WC}	ε_{WSO}	ε_{YPP}
Pooled	**OLS**	-9.035 (-2.538)	4.340 (1.177)	-5.190 (-4.292)	2.643 (1.224)	-1.334 (-1.579)
	GLS-AR1	-13.039 (-2.365)	4.423 (0.763)	-7.337	3.319 (1.073)	-2.250 (-1.732)
	2SLS	29.916	-9.656 (-0.425)	7.634 (0.268)	-5.028 (-0.336)	5.458
	RE	-9.035 (-2.538)	4.340 (1.177)	-5.190 (-4.292)	2.643 (1.224)	-1.334 (-1.579)
	FE	-1.664 (-4.374)	0.634 (1.307)	0.199 (0.524)	0.300 (1.023)	1.969 (5.726)
	RE-AR1	-6.975 (-2.628)	3.775 (1.380)	-4.120 (-3.182)	2.281 (1.347)	-0.894 (-1.379)
Country Specific	**OLS min.**	-3.905	-1.425	-0.548	-1.089	-4.497
	OLS average	-0.875	0.486	0.235	0.126	0.331
	OLS max.	0.823	3.194	1.086	1.174	1.807
	Shrinkage min.	-1.377	-0.187	-0.370	-0.402	0.329
	Shrinkage average	-0.803	0.280	0.211	-0.028	0.447
	Shrinkage max.	-0.327	0.869	0.730	0.440	0.672

† *t*-values in parentheses, calculated by the delta method. It is not meaningful to report average *t*-values for the average country-specific shrinkage and OLS estimates.

It is interesting to compare the results of Maddala et al. (1997), Baltagi and Griffin (1997) and Baltagi, Griffien, and Xiong (2000) with ours. It appears that all studies have the same general pattern with respect to the long-run elasticities. Average (or alternatively median) shrinkage long-run elasticities tend to be more inelastic (or have smaller absolute values) than the traditional pooled estimators. This might suggest that shrinkage estimators are biased downwards, or conversely that pooled estimators have an upward bias.

Country-specific OLS and shrinkage parameter estimates are presented in an appendix. In the Tables A1-A4 of the appendices the estimated coefficients from the country-specific shrinkage and OLS models are reported. Since it is a dynamic double-log model, the coefficients correspond to the short-run elasticities. A comparison of the OLS and shrinkage results reveals that the standard errors of the shrinkage estimator are always smaller. With few degrees of freedom one is more susceptible to get estimates that are theoretically or empirically unreasonable, due to small-sample problems. This is also the case here, but primarily for the OLS estimator. According to the results in Tables A1 and A3 the OLS estimate of the coefficient of the lagged dependent variable is negative for three countries. However, this is to a lesser extent the case for the shrinkage estimates. Only for the USA is the shrinkage estimate of the coefficient of the lagged dependent variable negative.

The short-run coefficients for the pooled models are not reported in the paper. It should be noted, however, that the coefficient of the lagged endogenous variable, $x_{i,t-1}$, is close to one in most of the pooled models, indicating near unit root. This is not a problem with the country-specific OLS and shrinkage estimates of the coefficient of the lagged variable, which generally are much lower, as one can see from Tables A1-A4. Baltagi and Griffin (1997) and Baltagi, Griffin and Xiang (2000), which both compare pooled and heterogeneous estimators, have similar findings on the lagged variable.

6.2 A More Detailed Study of Country-Specific Estimtates

Long-run elasticities for the individual OLS estimations are reported in the top half of Table 3. Most of the own-price elasticities (ε_{WFM}) are negative as expected, but with disparate values as -3.905 and 0.823 for countries with similarly structured meat producing sectors as Netherlands and Germany. Furthermore, six out of seven soybean meal cross-price elasticites

(ε_{WSM}) are positive, which correspond to soybean meal being a substitute to fish meal. Again, different cross-price elasticities of 3.194 for Netherlands and –1.425 for Germany are not very reasonable. The OLS cross-price elasticities for the other two feed inputs, ε_{WC} and ε_{WSO}, are mixed. Not many of them are significant and signs point in both direction. For example, in Germany cereals are substitutes and soybean oil is a complement for fish meal, while the opposite is the case in USA. The last column in Table 1 contains the output elasticities for pig and poultry production (ε_{YPP}). One would expect a positive correlation between pig and poultry production and fish meal consumption as fish meal is used extensively in compound feeds for pig and poultry. However, the results are mixed with only one significant parameter for Japan.

Table 3. Non-salmon producing countries' long-run elasticities for fish meal demand based on OLS and shrinkage estimates. †

Estimator	*Country*	ε_{WFM}	ε_{WSM}	ε_{WC}	ε_{WSO}	ε_{YPP}
OLS	Denmark	-0.504 (-1.909)	0.384 (1.206)	0.297 (1.204)	0.153 (1.006)	-0.010 (-0.016)
	France	-0.465 (-1.332)	0.190 (0.401)	0.293 (0.696)	-0.114 (-0.425)	-1.010 (-0.884)
	Germany	0.823 (1.211)	-1.425 (-1.463)	0.292 (0.368)	-1.089 (-2.032)	1.807 (1.170)
	Italy	-0.700 (-1.128)	0.188 (0.341)	1.086 (3.093)	0.185 (0.510)	-4.497 (-1.847)
	Japan	-0.058 (-0.166)	0.041 (0.132)	-0.173 (-0.518)	0.095 (0.350)	0.811 (1.963)
	Netherlands	-3.905 (-2.806)	3.194 (2.549)	0.399 (0.322)	1.174 (1.434)	4.700 (1.795)
	USA	-1.317 (-8.516)	0.828 (3.562)	-0.548 (-2.853)	0.479 (3.368)	0.513 (0.961)
Shrinkage	Denmark	-0.985 (-8.973)	0.468 (3.020)	0.018 (0.117)	0.122 (0.944)	0.509 (15.077)
	France	-0.595 (-4.265)	0.056 (0.355)	0.402 (2.786)	-0.205 (-1.670)	0.329 (5.879)
	Germany	-0.643 (-2.132)	0.117 (0.341)	0.379 (1.183)	-0.158 (-0.589)	0.392 (3.608)
	Italy	-0.746 (-3.667)	0.216 (0.892)	0.260 (1.126)	-0.077 (-0.399)	0.406 (5.345)
	Japan	-0.327 (-0.975)	-0.187 (-0.534)	0.730 (2.325)	-0.402 (-1.491)	0.337 (2.698)

	Netherlands	-0.945 (-6.466)	0.418 (2.083)	0.061 (0.305)	0.082 (0.493)	0.484 (9.469)
	USA	-1.377 (-19.807)	0.869 (16.318)	-0.370 (-8.789)	0.440 (12.109)	0.672 (21.333)

† *t*-values in parentheses, calculated by the delta method.

In summary, only a few of the aforementioned OLS elasticities are significant, and they are not very encouraging, as several of them have “wrongly” signed parameters. The overall picture of the OLS estimates is one of few significant parameters, many of which have implausible signs.

The shrinkage results in the lower half of Table 3 are altogether more encouraging. The own-price elasticities range from an elastic fish meal demand in USA with –1.377 to an inelastic demand in Japan with –0.327. It is not surprising that Japan has the most inelastic demand, as it is known to prefer higher quality fish meals. The price-elastic demand in USA also concur with our prior beliefs, as many US compound feed producers operate with simple least-cost formulas with respect to fish meal. For example, some US poultry producers have substituted marine proteins for vegetable proteins if the fish meal price exceeds 2.5 times the soybean meal price. The high cross-price elasticity of 0.869 agrees with a strong price relationship between fish meal and soybean meal in USA. The other cross-price elasticities suggest soybean meal and cereals are substitutes for fish meal, while soybean oil is a complement. USA is an exception where cereals are substitutes while soybean oil is a complement.

Table 4 reports long-run elasticites for the salmon producing countries. Like the results for the non-salmon producing countries, few of the elasticities from the OLS estimations are significant, and the ones that are significant show diverging tendencies between countries. The shrinkage estimator provides more significant and plausible estimates. All of the shrinkage estimates are in fact highly significant. Moreover, the elasticities are tightly distributed. Own-price elasticities vary between –0.192 for UK and –0.212 for Ireland, and is a considerable improvement from the OLS estimates where own-price elasticities varied between –0.567 in Chile and 0.792 in Ireland. Compared with countries which mainly import fish meal for use in pig and poultry feeds, demand in countries with intensive salmon production is markedly more inelastic.

Table 4. Salmon producing countries' long-run elasticities for fish meal demand based on OLS and shrinkage estimates.

Estimator	*Country*	ε_{WFM}	ε_{WSM}	ε_{WC}	ε_{WSO}	ε_{YPP}	ε_{YS}
OLS	Canada	0.374 (1.285)	0.142 (0.290)	0.106 (0.261)	0.341 (0.911)	1.119 (1.305)	0.052 (0.509)
	Chile	-0.482 (-1.632)	-0.012 (-0.046)	0.866 (1.566)	0.259 (1.074)	0.457 (1.323)	0.013 (0.222)
	Ireland	-1.300 (-0.250)	0.138 (0.037)	0.814 (0.204)	2.492 (0.757)	-5.172 (-0.394)	0.181 (0.075)
	Norway	0.452 (0.661)	0.211 (0.316)	-0.455 (-0.970)	-0.461 (-1.021)	-0.009 (-0.004)	0.615 (1.895)
	UK	-1.172 (-0.896)	1.200 (0.943)	0.157 (0.243)	0.248 (0.459)	0.162 (0.137)	-0.027 (-0.187)
Shrinkage	Canada	-0.200 (-8.217)	0.484 (20.978)	0.110 (4.663)	0.156 (6.825)	0.247 (14.397)	0.088 (3.913)
	Chile	-0.187 (-7.408)	0.533 (21.972)	0.144 (5.843)	0.186 (7.839)	0.318 (14.499)	0.097 (4.216)
	Ireland	-0.212 (-8.849)	0.459 (19.800)	0.092 (3.979)	0.139 (6.164)	0.211 (10.482)	0.083 (3.603)
	Norway	-0.204 (-8.327)	0.482 (20.190)	0.106 (4.427)	0.153 (6.635)	0.248 (11.318)	0.113 (5.001)
	UK	-0.192 (-7.617)	0.531 (22.471)	0.143 (5.867)	0.180 (7.681)	0.315 (17.694)	0.097 (4.306)

† *t*-values in parentheses, calculated by the delta method.

Soybean meal cross-price elasticities range from 0.459 in Ireland to 0.533 in Chile clearly indicating that fish meal and soybean meal are substitutes, but far from a 1:1 relationship between them. Cereals and soybean oil are also substitutes, but with considerably lower cross-price elastities than soybean meal. It is surprising that soybean oil is considered a substitute since unlike fish meal, it is mainly used an energy source in feeds. The output elasticities are all positive implying that increased pig, poultry and salmon production all lead to increased consumption of fish meal. It is also surprising that increased pig and poultry production have larger impact on fish meal demand than salmon production. One possible explanation for this can be that high collinearity between the time trend of the model and salmon output leads to a downward bias in the salmon output elasticity.

6.3 Bootstrap Analysis and Confidence Intervals

In the case of the shrinkage estimator, t-values of the long-run elasticities computed by the delta method are generally high. However, we have pointed out in the introduction the problems with standard asymptotic methods of constructing confidence intervals for long-run elasticities, because standard methods such as the delta method rely on normal (or symmetric) distributions and exogenous regressors. A relevant study in our context, which does focus on the construction of confidence intervals, is Li and Maddala (1999), who estimate demand models with lagged dependent variables estimated on panel data, but they only analyse OLS estimates.

In the following we present bootstrapped confidence intervals as an alternative measure of the confidence intervals. Bootstrapped distributions of the long-run elasticities are not restricted to be normal or symmetric. There are several bootstrap methods to choose among. Among the most popular are the percentile method and the percentile-t method (Kazimi and Brownstone, 1999; Li and Maddala, 1999). We use the percentile method, due to its superior performance in Monte Carlo studies in the case of shrinkage estimators (Kazimi and Brownstone, 1999).

Table 5. Shrinkage Estimates of Long-Run Elasticities with Bootstrapped Confidence Intervals

Country	*Statistic*	ε_{WFM}	ε_{WSM}	ε_{WC}	ε_{WSO}	ε_{YPP}	ε_{YS}
Canada	L(5%)	-0.600	-0.363	-0.455	-0.327	-0.836	-0.094
	Mean	-0.200	0.484	0.110	0.156	0.247	0.088
	U(95%)	0.369	0.908	0.617	0.567	1.159	0.217
	U-L	0.969	1.272	1.072	0.895	1.995	0.312
Chile	L(5%)	-0.626	-0.195	-0.565	-0.235	-0.417	-0.054
	Mean	-0.187	0.533	0.144	0.186	0.318	0.097
	U(95%)	0.411	0.858	0.868	0.548	0.919	0.195
	U-L	1.036	1.053	1.433	0.783	1.336	0.249
Ireland	L(5%)	-0.694	-0.340	-0.696	-0.303	-1.221	-0.157
	Mean	-0.212	0.459	0.092	0.139	0.211	0.083
	U(95%)	0.575	0.984	0.659	0.579	1.434	0.301
	U-L	1.270	1.323	1.355	0.882	2.655	0.458
Norway	L(5%)	-0.714	-0.328	-0.610	-0.283	-2.531	-0.355
	Mean	-0.204	0.482	0.106	0.153	0.248	0.113
	U(95%)	0.685	1.000	0.764	0.569	1.536	0.291
	U-L	1.399	1.328	1.374	0.852	4.066	0.646
UK	L(5%)	-0.942	-0.443	-1.053	-0.370	-1.399	-0.134
	Mean	-0.192	0.531	0.143	0.180	0.315	0.097
	U(95%)	0.706	1.294	0.847	0.596	2.121	0.314
	U-L	1.649	1.737	1.900	0.966	3.521	0.449

Table 5 reports the country sample-mean elasticity, together with the 5% and 95% quintiles (L(5%) and U(95%)), and the 90% confidence interval (U-L). The general impression is that the bootstrapped confidence intervals are rather large and fail to provide statistical support for the sign of the elasticity. For example, while the asymptotic t-ratios provided firm statistical support for negative own price elasticities of fish meal in table 4, this is no longer the case when the bootstrapped confidence intervals is used as the basis for hypothesis tests. For all five countries the upper limit of the 90% confidence interval, the 95% quintile, is positive.

These results might be viewed as somewhat disappointing, but are not surprising, since the predominant conclusion from studies of the bootstrap method is that it does not to provide an improvement over other methods (Li and Maddala, 1999). However, one has to question the trade-offs related to the shrinkage estimator. When the number of individuals or observations increases, the shrinkage estimator will approach the pooled estimator. This implies that the distribution imposed on the parameters will be directly related to the sample size, and as such convey a sense of artificiality, since it is not a limiting distribution. Bearing this in mind, the shrinkage estimator can still be purposeful, in that imposing a Gaussian distribution on parameters across the individuals in a data set can be viewed as a sensible assumption.

We do not present bootstrapped confidence intervals for the OLS estimates here. However, the bootstrapped OLS confidence intervals are considerably larger than the shrinkage confidence intervals. Hence, the relative performance of the shrinkage estimator in terms of prediction is better regardless of whether standard asymptotic or bootstrapped confidence intervals are employed.

7. SUMMARY AND CONCLUSIONS

In this study we investigate the small-sample performance of the empirical shrinkage estimator suggested in Maddala et al. (1997). The initial impression is that the shrinkage estimator performs well compared with the single-equation OLS and pooled estimators, both in terms of more plausible results and more significant elasticity estimates. The price elasticites are generally of lower magnitudes for the shrinkage estimator compared with the pooled estimators. Interestingly, it appears that this pattern is also found in the aforementioned comparative studies of pooled and heterogeneous estimators, although this is not entirely clear-cut. Still, it might indicate that the shrinkage estimator is biased downwards (in absolute value), or, conversely, that the pooled estimators are biased upwards.

Both Baltagi and Griffin (1997) and Baltagi, Griffin and Xiong (2000) find that pooled econometric models outperform heterogeneous models. Particularly when we compare the shrinkage estimator with the pooled estimators, we find the opposite. The explanation for the discrepancy between our study and the two aforementioned studies is probably differences in the relative variability of the data between individual time series and panels. The cross-sectional dimension is much larger in the two other studies, giving rise to the possibility of a much higher cross-sectional variation than in our case of only 5 and 7 cross-sectional units in the two data sets we estimate on.

Returning to the average shrinkage estimates, they indicate fish meal demand is *inelastic* in own price for both salmon and non-salmon producing countries, although more so for salmon producing countries, corresponding with our prior beliefs. In contrast, the results from the pooled estimators generally indicate *elastic* fish meal demand. In the shrinkage estimation both meat and salmon production output elasticities are positive, contrary to many of the other estimators. However, the output elasticities are higher for meat production than for salmon production, which is somewhat surprising. It might indicate that the separability issue poses problems. The overall picture is still that of salmon producing countries having a significantly more inelastic demand than non-salmon producing countries, even if output elasticities for meat are higher than for salmon. This indicates that growth of salmon production will increase the scarcity of fish meal.

On a country-specific basis, the shrinkage estimator is superior to the single-equation OLS estimates; the shrinkage estimates obey the law of demand and Le Chatelier principle as own-price elasticities are more inelastic in the short run than in the long run. Also, while the OLS estimates barely produce any significant parameter estimates, most of the country-specific shrinkage estimates are significant.

For the construction of confidence intervals for the elasticities, we first used a standard Taylor's series expansion, sometimes referred to as the delta method. A caveat with this method is that it assumes a normal distribution, which is doubtful in the case of the shrinkage estimator. Consequently, we bootstrapped the elasticities in order to approximate any potential non-normal underlying distributions. The general impression is that the bootstrapped confidence intervals are rather large and fail to provide statistical support for the sign of the elasticities, and as such are somewhat disappointing. It should however be emphasised that the country-specific OLS estimates suffered even more, in terms of the bootstrap removing support for the small-sample estimates.

According to the empirical results from the shrinkage model, fish meal demand is in general inelastic in own price, but also highly inelastic in salmon output, leading to a somewhat mixed picture with respect to the effects of growth in salmon production. Even with the reasonable assumption of a highly inelastic supply curve for fish meal, the shrinkage estimator predicts that growth in salmon output should only cause a small shift in the demand curve, thus leading to only a moderate effect of the price fish meal. It does not seem reasonable that increased salmon production has such a small effect on demand, and the result probably reflects a separability problem in our model. It has not been possible to separate the livestock and the salmon sectors' demand for fish meal in an ideal fashion. We have been able to separate countries that mainly use fish meal for pig and poultry production. However, there is no country that solely uses fish meal for salmon aquaculture. Consequently it is much harder to identify the effect of salmon production on fish meal demand than the effect of pig and poultry production.

In this respect, the model seems more successful in capturing differences in own-price elasticities between the salmon sector and the pig and poultry sector. A likely explanation for this discrepancy is that the fish meal price vary more than the salmon output, leaving it more forceful as an explanatory variable than the trended salmon output variable. The parameter estimate of salmon output is possibly muddled by the presence of two other trended variables in the model specification, the pig and poultry output and the time trend. If one considers that the model likely understates the effect of salmon production growth on fish meal demand, then the implications of increased salmon aquaculture becomes clearer. Given that salmon production continues to grow at its current pace and feed technology only changes moderately then prices for marine proteins will increase. Increasing fish meal prices will eliminate profitability margins not only in salmon farming, but also in farming of other carnivorous species. It is the result of an inelastic demand for fish meal in salmon feeds, reflecting the dependence on marine raw materials with current feed technology. This is a situation should provide incentives for research and development that will induce innovations for alleviating the marine protein requirements in fish feed technology. The degree of success with such research and development efforts will be crucial for the further development of intensive aquaculture.

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Appendix. Country Specific OLS and Shrinkage Parameter Estimates

Table A.1. Country Specific OLS Estimates for 7 Salmon Non-Producing Countries

Variable		$lnX_{FM,i,t-1}$	$lnW_{FM,i,t}$	$lnW_{SM,i,t}$	$lnW_{C,i,t}$	$lnW_{SO,i,t}$	$lnY_{PP,i,t}$	T	*Const.*
Denmark	Coeff.	-0.488	-0.750	0.572	0.442	0.227	-0.015	0.129	13.503
	St.err.	0.199	0.371	0.368	0.294	0.193	0.864	0.005	0.034
France	Coeff.	0.511	-0.228	0.093	0.144	-0.056	-0.494	0.028	13.092
	St.err.	0.262	0.176	0.190	0.161	0.115	0.411	0.002	0.017
Germany	Coeff.	0.130	0.715	-1.239	0.254	-0.947	1.571	-0.096	-5.327
	St.err.	0.258	0.591	0.556	0.643	0.406	0.941	0.009	0.065
Italy	Coeff.	0.276	-0.507	0.136	0.787	0.134	-3.257	0.064	52.423
	St.err.	0.248	0.410	0.294	0.311	0.238	1.458	0.006	0.040
Japan	Coeff.	0.224	-0.045	0.031	-0.134	0.073	0.629	-0.009	1.753
	St.err.	0.315	0.222	0.198	0.182	0.162	0.221	0.003	0.020
Netherlands	Coeff.	0.497	-1.966	1.608	0.201	0.591	2.366	-0.023	-29.848
	St.err.	0.191	0.538	0.570	0.594	0.378	1.323	0.010	0.073
USA	Coeff.	-0.246	-1.640	1.031	-0.683	0.597	0.639	-0.004	9.198
	St.err.	0.102	0.153	0.238	0.204	0.147	0.564	0.003	0.021

Table A.2. Country Specific Shrinkage Estimates for 7 Salmon Non-Producing Countries

Variable		$lnX_{FM,i,t-1}$	$lnW_{FM,i,t}$	$lnW_{SM,i,t}$	$lnW_{C,i,t}$	$lnW_{SO,i,t}$	$lnY_{PP,i,t}$	T	*Cons.*
Denmark	Coeff.	0.302	-0.688	0.327	0.013	0.085	0.355	0.039	4.538
	St.err.	0.115	0.027	0.014	0.013	0.012	0.007	0.003	0.013
France	Coeff.	0.503	-0.296	0.028	0.200	-0.102	0.163	0.009	4.349
	St.err.	0.056	0.026	0.013	0.013	0.012	0.003	0.001	0.011
Germany	Coeff.	0.500	-0.321	0.058	0.190	-0.079	0.196	-0.024	4.366
	St.err.	0.125	0.027	0.014	0.014	0.013	0.009	0.005	0.013
Italy	Coeff.	0.445	-0.414	0.120	0.144	-0.043	0.225	0.002	4.407
	St.err.	0.109	0.027	0.014	0.014	0.012	0.006	0.003	0.013
Japan	Coeff.	0.612	-0.127	-0.073	0.284	-0.156	0.131	-0.007	4.279
	St.err.	0.078	0.027	0.013	0.013	0.012	0.003	0.002	0.012
Netherlands	Coeff.	0.334	-0.629	0.278	0.041	0.055	0.322	-0.001	4.508
	St.err.	0.133	0.028	0.014	0.014	0.013	0.010	0.006	0.013
USA	Coeff.	-0.170	-1.611	1.017	-0.433	0.515	0.786	-0.005	4.976
	St.err.	0.079	0.026	0.013	0.014	0.012	0.003	0.002	0.012

Table A.3. Country Specific OLS Estimates for 5 Salmon Producing Countries

Variable		$lnX_{FM,i,t-1}$	$lnW_{FM,i,t}$	$lnW_{SM,i,t}$	$lnW_{C,i,t}$	$lnW_{SO,i,t}$	$lnY_{PP,i,t}$	$lnY_{S,i,t}$	T	$Const.$
Canada	Coeff.	0.211	0.295	0.112	0.084	0.269	0.883	0.041	0.009	-9.247
	St.err.	0.316	0.211	0.277	0.209	0.259	0.493	0.055	0.004	0.028
Chile	Coeff.	-0.567	-0.756	-0.019	1.357	0.406	0.716	0.020	0.057	3.956
	St.err.	0.259	0.431	0.397	0.685	0.302	0.375	0.069	0.009	0.060
Ireland	Coeff.	0.792	-0.270	0.029	0.169	0.518	-1.074	0.038	0.058	11.506
	St.err.	0.433	0.726	0.517	0.809	0.436	0.941	0.174	0.009	0.059
Norway	Coeff.	0.038	0.435	0.203	-0.438	-0.444	-0.009	0.591	-0.027	6.319
	St.err.	0.256	0.657	0.479	0.444	0.322	1.539	0.220	0.008	0.055
UK	Coeff.	0.504	-0.581	0.595	0.078	0.123	0.080	-0.014	0.018	4.011
	St.err.	0.354	0.301	0.234	0.260	0.108	0.531	0.041	0.003	0.021

Table A.4. Country Specific Shrinkage Estimates for 5 Salmon Producing Countries

Variable		$lnX_{FM,i,t-1}$	$lnW_{FM,i,t}$	$lnW_{SM,i,t}$	$lnW_{C,i,t}$	$lnW_{SO,i,t}$	$lnY_{PP,i,t}$	$lnY_{S,i,t}$	T	$Const.$
Canada	Coeff.	0.353	-0.129	0.313	0.071	0.101	0.160	0.057	0.023	2.031
	St.err.	0.014	0.015	0.015	0.015	0.015	0.007	0.010	0.002	0.014
Chile	Coeff.	0.376	-0.117	0.332	0.090	0.116	0.198	0.061	0.007	2.034
	St.err.	0.014	0.015	0.015	0.015	0.015	0.013	0.014	0.006	0.016
Ireland	Coeff.	0.342	-0.139	0.302	0.061	0.091	0.139	0.054	0.034	2.029
	St.err.	0.014	0.015	0.015	0.015	0.015	0.012	0.013	0.004	0.015
Norway	Coeff.	0.356	-0.131	0.311	0.068	0.099	0.159	0.073	0.065	2.031
	St.err.	0.014	0.015	0.015	0.015	0.015	0.013	0.011	0.005	0.015
UK	Coeff.	0.376	-0.120	0.331	0.089	0.112	0.196	0.060	-0.003	2.034
	St.err.	0.014	0.015	0.015	0.015	0.014	0.008	0.007	0.002	0.013

PAPER 6

Norwegian Salmon Aquaculture and Sustainability: The Relationship Between Environmental Quality and Industry Growth

by

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Abstract This paper discusses the relationship between industry growth and environmental quality in the context of salmon aquaculture. It is argued that industry growth can reduce pollution by inducing more technological innovations for industry-specific pollution-reducing inputs. This increases the elasticity of substitution between conventional factors of production on the one hand, and pollution on the other, and therefore enables a greater degree of internalization of environmental problems. Four indicators of pollution are examined for Norwegian salmon aquaculture. The salmon aquaculture industry is one in which growth is associated with reduced environmental problems not only in relative, but also in absolute terms.

Key words Environmental Kuznets curve, induced innovation, industry growth, salmon aquaculture.

I would like to acknowledge the helpful comments of Frank Asche, Ragnar Tveterås, and two anonymous referees. Any mistake is the sole responsibility of the author. The research was supported by grant from The Research Council of Norway, Project No. 24445.

Introduction

In many cases, industry expansion gives rise to environmental concerns because pollution is thought to be positively correlated with output. However, many economists have supported the view that economic growth can often be beneficial for the environment. At the aggregate level, this view is formulated in the environmental Kuznets curve (EKC) hypothesis, which suggests that some pollutants have an inverse U-shaped relationship with countries' income.[56] In this paper, we look at the relationship between environmental quality and growth at a more disaggregated level, which enables focus on pollution and industry growth. The change in perspective from macroeconomic growth to industry growth can provide new insights into the relationship between growth and pollution. In particular, Lopéz (1994) shows that economic growth can reduce the degradation of natural resources only if producers internalize the effects of stock feedback on production. Sustainable development, therefore, requires that industries adopt more environmentally friendly practices and technology as the economy grows, since industries are the major source of many pollutants.

Industry decision making in relation to environmental issues is not based on growth in the economy as such, but rather on profit maximization. In this respect, industry growth is more relevant to environmental practices than to economic growth because industry growth more directly affects the framework within which firms operate. Moreover, one would expect individual firms to respond in a similar way to environmental concerns given that practices are similar for all agents within an industry. This supports the notion that industries represent a natural aggregation level. On the other hand, different industries (or the same industry in different regions) will respond differently to environmental concerns due to heterogeneity between industries (regions); e.g., in terms of the technology and the types of inputs used and

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[56] Most of the empirical studies of the EKC are comparative studies on a country level. (E.g., Grossman and Krueger 1995; Shafik and Bandyopadhyay 1992; Selden and Song, 1994; Panayotou, 1993; Cole, Rayner, and Bates 1997.)

governmental legislation. Some will have incentives to internalize environmental problems, while others will not. The degree to which producers internalize environmental effects suggests two different measures of environmental improvements: (1) *relative* and (2) *absolute* reductions in environmental degradation. The former indicates that industries have incentives to internalize environmental problems, where the pollution per unit produced (pollution intensity) is reduced. However, a reduction in pollution intensity may not offset the increase in pollution-generating activity (production), hence the absolute amount of environmental degradation may still increase. Under condition (2), the industry not only has incentives to internalize, but actually improves its environmental practices to such a degree that pollution decreases, despite increased industry production.

The Norwegian salmon aquaculture industry has been the global market leader since the early 1980s and is also at the forefront of technological innovation. Annual growth in Norwegian salmon production has been rapid, averaging 21% between 1984 and 1999 reaching a total output of 464,000 metric tonnes by 1999. The value of Norwegian salmon production increased ten-fold from \$0.13 billion to \$1.3 billion over the same period (FAO 2000). Norway is the largest salmon producer in the world, with 46% of the global market in 1999, followed by Chile, the UK, and Canada with market shares of 20%, 14%, and 8%, respectively. Chile, the fastest-growing salmon aquaculture producer in the world, began catching up with Norway during the 1990s.

A number of environmental concerns has emerged in the wake of the rapid expansion of salmon aquaculture, many of which can be attributed to the intensive nature of salmon farming. These concerns have ranged from effluent discharges, escaped farmed salmon, diseases, and the use of medicines and chemicals, to more global concerns, such as the taxation of wild fish stocks, which has been prompted by the increased consumption of fish meal and fish oil (Folke, Kautsky, and Troell 1994; Black *et al.* 1997; Asche, Guttormsen, and Tveterås 1999; Asche and Tveterås 2000; Naylor *et al.* 2000). The industry has also faced considerable scrutiny from media and interest groups in Norway and elsewhere because of these concerns. However, most indicators of environmental quality show signs of improvement, which suggests that the Norwegian salmon aquaculture industry is addressing these concerns. It also indicate that salmon farmers have economic incentives to internalize environmental problems, as suggested by Asche, Guttormsen, an Tveterås (1999).

This paper is organized as follows. The first section presents a theoretical framework for analyzing the relationship between industry growth and environmental quality. The focus is on the conditions for environmental improvement on the one hand, and the relationship between industry growth and the environment on the other. Discussion sounds methodological issues relating to empirical testing of the relationship between industry growth and environmental quality. The following section uses the framework outlined in the theoretical section to examine the development of environmental problems in Norwegian salmon aquaculture. A discussion and summary complete the paper.

Theoretical Framework

Conditions for Environmental Improvement

Although it is reasonable to theorize that increasing economic activity increases pollutant emissions, it has been argued that economic growth can reduce the degradation of natural resources if producers internalize their stock feedback effects on production (Lopéz 1994). Given such a view, it is important to determine the conditions necessary for the internalization of environmental problems, since sustainable development depends on these conditions being satisfied. Broadly speaking, there are two main reasons for a profit-maximizing firm to address the environmental problems that arise from its activity: either legislation forces the firm to clean up, or it is profitable for the firm to do so. Both imply internalization of the environmental problem, since the firm bears the social costs that arise from its own activity. However, policy measures are usually adopted because industries themselves do not have incentives to address these issues. This is usually true in cases where costs are more dispersed, as is the case with CO_2 emissions and other airborne pollutants from which there are no feedback effects on productivity (Shafik and Bandyopadhay 1992). Local pollution tends to be the type that generates negative feedback effects on productivity. Reduced productivity provides firms with incentives to internalize the feedback effects into their decision-making given that they have property rights over the environmental resource. This can be illustrated by using the following profit-maximization problem:

$$\max_{y} \pi = py - c(y) - \mathbf{e}(y) \qquad (1)$$

where py is income as a function of price, p, and the produced quantity, y; $c(y)$ denotes production costs; and $\mathbf{e}(y)$ is vector of negative feedback emissions of pollutants as a function of the produced quantity. We assume $c'(y) > 0$ and $\sum_i e_i'(y) \geq 0$ so that increased production increases the cost of production, c, and emissions, $\mathbf{e}$, if the sum of the feedbacks on cost is positive. Firms are indifferent to the effects of the emissions if $\Sigma e_i' = 0$. Firms have incentives to improve their environmental practices if there are negative feedback effects on productivity; i.e., $\sum_i e_i' > 0$.

Note that in equation (1) emissions are solely a function of output, y. In general, this will only be true if the elasticity of substitution between conventional inputs and pollution approaches zero; i.e., in the limiting case of Leontief technology. In more realistic cases, in which the elasticity of substitution is greater than zero, it is possible to reduce pollution by upgrading equipment and technology. This means that the emissions, $\mathbf{e}$, can be reformulated as $\mathbf{e}(y,\mathbf{z})$, where e is now a function of output, y, and a vector of inputs, $\mathbf{z}$, with $\mathbf{e}_y > 0$ and $\mathbf{e}_\mathbf{z} < 0$. This is a reasonable description of salmon aquaculture, in which an array of different inputs can be used to reduce environmental problems. These include, most importantly, industry-specific inputs, such as feeds and feeding technology, vaccines, and medicines.

Increased productivity and reduced costs are not the only reasons why firms may find it profitable to invest in more environmentally friendly practices. Such investments can also be prompted by consumer behavior. For example, food safety issues and the demand for more environmentally-friendly food products have stimulated markets for organic produce. This has influenced decision-making in food industries, since there is a belief that products, which are perceived to be more environmentally friendly are priced at a premium and, in some cases, are of a higher quality than conventional products. Studies support the notion that consumers are becoming increasingly concerned with issues relating to food safety and sustainability in relation to seafood production by signaling a willingness to pay a higher price for more environmentally friendly seafood products (see Wessells and Anderson 1995; Wessells Johnston, and Donath 1999; Johnston *et al.* 2001).

Industry Growth and Environmental Quality

Before the role of industry growth is discussed, it is important to clarify what is meant by growth in this context. The primary focus of this study is on industries that have reached a size that enables them to capitalize on increased R & D efforts. In this context, the problem with smaller industries is that they lack the capability to undertake the investments required to develop more environmentally friendly production technologies. An important point is that technology and inputs are often very industry-specific; they cannot be applied in other industries. When large investments are required and there is uncertainty associated with the development of new technologies (or intermediate inputs), potential investors and innovators may be deterred by a small market (industry). In contrast, expanding industries find it easier to attract capital simply due to the implications of growth. For investors, growth represents the prospect of good returns on capital,, while suppliers see growth providing an expanding market base for their own products and services. Still, it is apparent that the scale of activity must exceed some critical threshold if suppliers and investors are to deem such investments profitable. Moreover, if the industry has incentives to internalize its environmental impacts, then it is most likely that these investments will be channeled towards abatement technologies, hence increasing the elasticity of substitution between conventional factors of production and pollution. This result can be expected whether the internalization is induced by governmental regulations, 'green' markets, or individual property rights, unless internalization signifies some constraint on the industry's output. If this is the case, unsustainable practices may be causing the industry to contract.

Measuring the Effects of Industry Growth on Environmental Degradation

To test if an industry has incentives to internalize environmental problems, it is useful to formulate an economic model in the form of a cost-minimization or profit-maximization problem. However, because data availability tends to be a restricting factor, it is necessary to consider other ways of modeling this kind of problem. A variation on the EKC model, but at a more disaggregated level, is appropriate given that the effect of growth on environmental quality is of primary interest. In EKC models, the independent variable used to proxy economic growth is usually an income measure, while the dependent variable is an indicator of environmental quality. In this paper, it is industry growth, not economic growth, that is of interest. Industry output can be used to proxy industry growth since it measures an industry's level of activity. This suggests the following relationship:

$$E_{it} = f(Y_{it}) = \alpha + \beta_1 Y_t + \beta_2 Y_t^2, \qquad (2)$$

where E_{it} is an environmental indicator (to be defined subsequently). The parameters, β_1 and β_2, capture trends in polluting intensity, while Y_t represents the size of the industry and thus also polluting activity. An inverted U-shaped relationship between pollution and industry size corresponds to $\beta_1 > 0$ and $\beta_2 < 0$. This implies that the industry internalizes environmental problems.

We examine two different aspects of this relationship by considering two different measures for the environmental indicator, E_{it}, namely *relative* and *absolute* pollution. A relative reduction in pollution corresponds to an inverted U-shaped relationship between the amount of pollution per unit produced and industry growth. A reduction in pollution intensity indicates that the industry has incentives to internalize environmental problems. To a large degree, this dictates whether emerging industries will be environmentally sustainable or not, and is, therefore, important. However, it is the absolute level of pollution that challenges the resilience of the environment, and this is the most important measure in the long run. An inverted U-shaped relationship between E_{it}, indicating the absolute level of pollution, and industry growth implies that environmental quality is improving. In this case, since industry growth corresponds to an increasing degree of internalization, it may be beneficial for environmental quality. This paper uses four pollution indicators (E) for salmon aquaculture: the feed conversion rate; antibiotics use; chemicals use; and salmon escapees.

The Environmental Concerns of the Salmon Farming Industry

Consider now the environmental issues in Norwegian salmon aquaculture. Naylor *et al.* (2000) outline two main groups of environmental problems for the salmon farming industry. The first group relates to the negative effects of salmon farming on the environment, wild fish, and the ecological basis of other living things. These are mainly local and regional concerns. Issues belonging to this group include diseases, medicine use, the impact of organic waste from farms on benthic fauna, eutrophication, the escape of farmed salmon, sea lice, and contamination of the genetic make-up of wild salmon. The second group relates to the pressure put on wild fish stocks by salmon farming's use of large quantities of fishmeal and fish oil in the salmon feeds. This is a global issue. Other global issues include the presence of toxins, such as dioxins and PCBs in the marine inputs, and possible GMO inputs in the feed. This paper examines only local and regional environmental issues. For a discussion of global issues, see Asche and Tveterås (2000).

Organic Waste

Effluence discharges are one of the major environmental concerns in salmon farming and account for most of the pollution around fish farms. The organic waste, which comes primarily from fish feces and waste feed, can build up on the seabed if the rate of decomposition is sufficiently low, thereby damaging the local fauna. Another problem is that the waste leads to higher concentrations of nutrients in the sea, which increase the risk of eutrophication (Folke *et al.* 1994). However, Black *et al.* (1997) point out that eutrophication depends on the nutrients being discharged and on the resilience of the local environment. A strong current increases the availability of oxygen, which is needed for the decomposition of the organic matter, and also contributes to a wider dispersion of it. Hence, the organic load directly under the cages is reduced, thereby alleviating the challenge to the environmental resilience capacity. Since seabed topography also influences the resilience of the environment, the siting of cages is important.

However, organic waste sedimentation does not only pose a problem for the local fauna, but also for salmon farmers due to negative feedback effects on productivity. The biological decomposition process for the waste reduces the availability of oxygen in the surrounding area, thus lowering the resistance of farmed fish to diseases. Moreover, depletion of the oxygen level in the decomposition process can produce toxic gasses, which, if released, are harmful to farmed fish (Wallace 1993). Thus, production risk increases with higher feed use because of the negative environmental feedback (Asche and Tveterås 1999; Tveterås 1999, 2000). Therefore, risk-averse salmon farmers would minimize feed use and/or take other measures to reduce negative feedback effects on productivity. As feed costs account for over 40% of the total production costs in salmon farming, there is also a cost argument for reducing feed.

Salmon farmers have responded to these problems. First, feed and feeding technology have improved considerably over the last two decades. Figure 1 shows that the feed conversion ratio (FCR) declined between the 1980s and 1990s. It has fallen from almost three kilos of feed required to produce one kilo of salmon in 1980 to just over one kilo required in 2000. Most of this reduction is due to a greater use of lipids in the feed: a 1% increase in the inclusion rate of lipids leads to a 1% reduction in organic waste. However, new feeding systems have also contributed to reducing the FCR by lowering the feed waste.

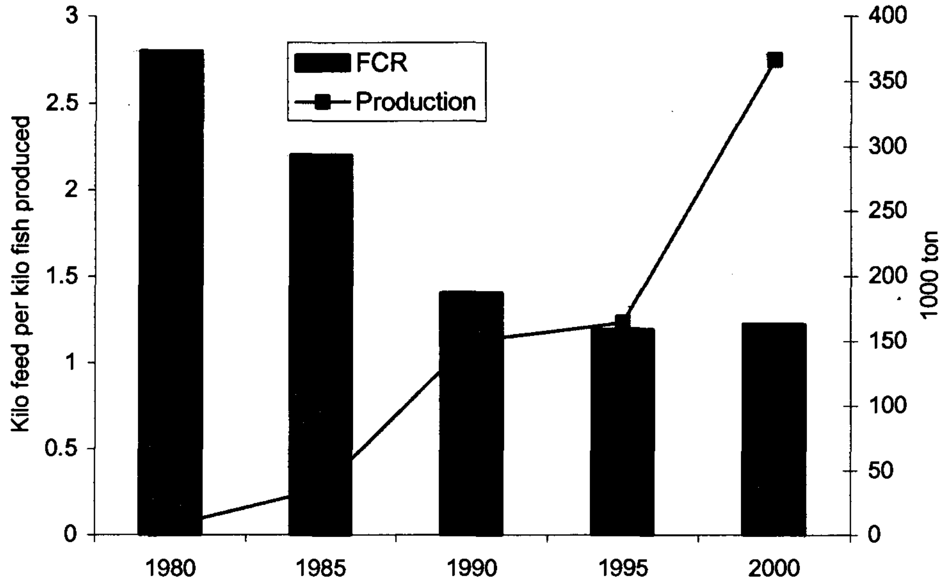

Figure 1. Feed conversion rate 1980-2000

(Source: Austreng (1994) and Directorate of Fisheries)

Second, most salmon farms have moved to areas with stronger currents, deeper waters, and more suitable seabed topography, which significantly reduces the accumulation of waste sediments and negative feedback effects on productivity. In areas with unsustainable locations, salmon farms have disappeared. Thus, the combination of new sea cage technology, which allows sites to be moved to more exposed locations and enables rotation between different sites, and improved feed and feeding technology has significantly increased the elasticity of substitution between traditional factors of production and effluence discharges. This undertaking has probably been induced by a combination of environmental feedback effects on productivity and a general effort to reduce costs. Consequently, salmon farmers have internalized many of the problems related to organic waste so that the environmental quality of the areas surrounding the salmon farms has improved since the late 1980s.

There is little evidence that the capacity for resilience of the local environment is currently being challenged. Since there is a negative relationship between FCR and output, the reduction in the FCR implies that there has been a decline in relative discharges of organic waste since 1980, indicating an inverted U-shaped relationship in relative terms. It is not possible, however, to judge from the available data whether there has been an inverted U-shaped relationship between the absolute level of effluence discharges and the growth of the salmon aquaculture industry in Norway. Calculating total feed consumption by multiplying the FCR by the salmon production, we find that total feed consumption has increased, which is not surprising given the explosive growth of salmon farming. However, this does not necessarily imply that the absolute level of organic waste has increased, however, since there is not a one-to-one relationship between feed consumption and feed waste. If the feed spill percentage declined substantially, there might be an inverted U-shaped pattern for the absolute level of organic waste relative to industry growth.

In this context, it is interesting to note that the improvements in the feed and feeding regimes have, to a large degree, been made by the feed industry, not by the salmon farmers. Some improvements in the FCR have been due to on-farm experiments with feeds and feeding systems. However, the feed technology changed in the late 1980s and early 1990s when almost all salmon farmers abandoned wet and moist feeds in favor of dry. Dry feeds are commercially manufactured and, therefore, not made on-farm. Since then, feed development has mainly been conducted by the feed industry. This indicates that, in the 1990s, the salmon farming industry enjoyed external economies of scale with respect to improved feed and feeding technology.

Antibiotics and Chemicals

The use of antibiotics in the treatment of diseases is another controversial issue concerning the environmental practices of salmon aquaculture. Antibiotic use can lead to antibiotic resistance in fish and other living organisms. In particular, the extensive use of antibiotics in the late 1980s provoked much criticism from consumers. Since then, the use of antibiotics has been virtually eliminated.

Figure 2 shows that the use of antibiotics forms an inverted U-shaped pattern in absolute terms. First, salmon farmers responded to the disease problem in the 1980s by increasing the use of antibiotics. The first large disease outbreaks were bacterial coldwater vibrosis in 1986 and furuncolosis in 1990-1992. Two factors were important in reversing the trend towards an increasing use of antibiotics. First, the relocation of salmon farms to more suitable locations generally improved fish health. Second, the introduction of an oil-based vaccine in 1992, which was effective against bacterial diseases, made antibiotics more or less redundant. Thus, since peaking in 1987, the use of antibiotics has been on a downward trend, despite a temporary increase in usage following the furuncolosis outbreaks in 1990. This contrasts with the upward-sloping trend for production, which is shown in Figure 1. After the first vaccinations took effect in 1993, antibiotics were hardly used.

The development of the oil-based vaccine can be seen as the result of the salmon industry becoming an attractive market for industry-specific pharmacy services and products. Industry growth therefore made it profitable for the pharmacy industry to invest in the development of such vaccines, which would otherwise not have been available until much later. Thus, industry growth has helped to reduce the use of antibiotics, not only in relative terms, but also in absolute terms.

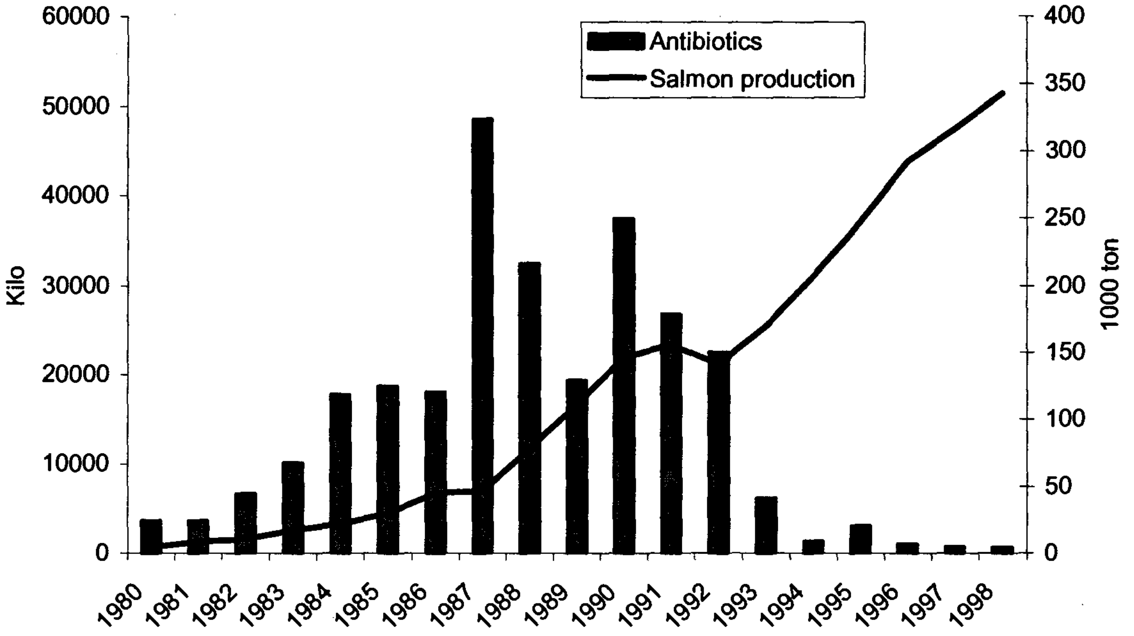

Figure 2. Use of antibiotics in the Norwegian salmon farming industry, 1980-1998 (Source: The Norwegian Medicinal Depot)

The same overall trends are found in the use of chemicals. Figure 3 shows that since the mid-1980s, the use of chemicals has demonstrated a downward trend. Because the time-series only dates back to 1984, we only observe the downward-sloping trend in the use of chemicals. However, we can infer an inverted U-shaped pattern for chemicals, given that their use must have been close to zero in the 1970s when intensive salmon aquaculture began. Chemicals are mainly used for cleaning cages and for treating salmon lice. Wrasses have been introduced as a more environmentally friendly method of treating sea lice because they feed on the sea lice that live on farmed salmon. On its own, this measure is not sufficient to eliminate the sea lice. Salmon farmers must still rely on chemicals to treat infected fish, but they use considerably less now than they did in the mid-1980s. Yet, as in the case of antibiotics, we observe a decline in the use of chemicals as the salmon industry expands.

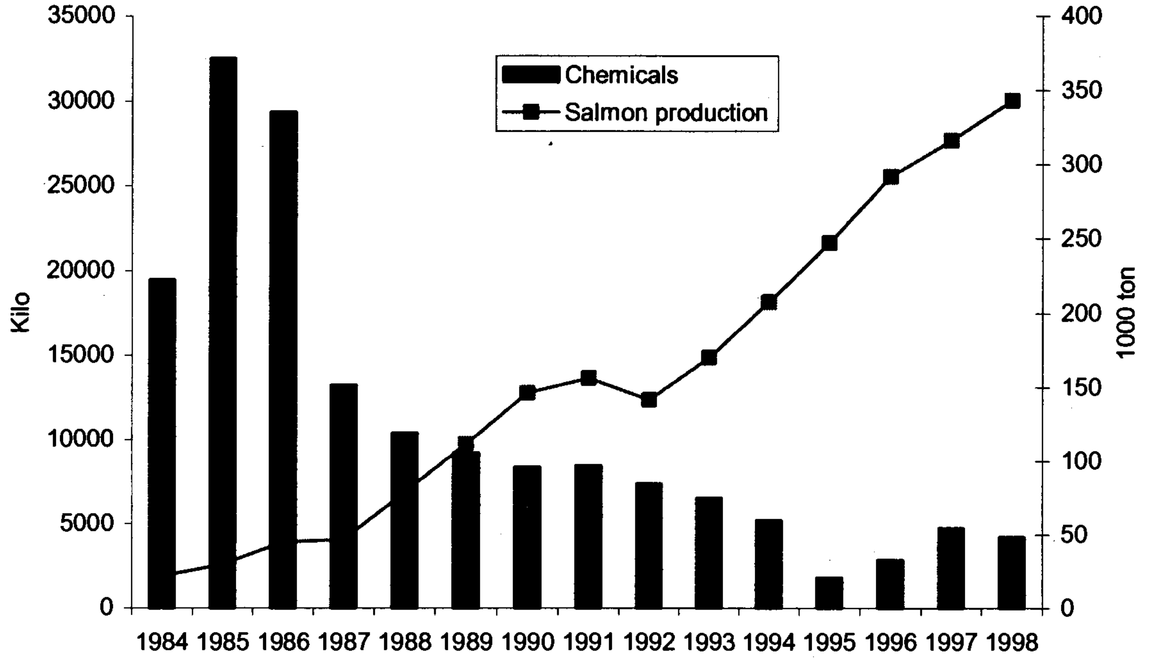

Figure 3. Use of chemicals in the Norwegian salmon farming industry, 1984-1998
Source: The Norwegian Medicinal Depot

Salmon Escapees and Sea Lice

The issue of salmon escapees is controversial because of its potential negative impact on wild salmon stocks. The short-term effects of escaped farmed salmon include competition and breeding with wild salmon, the spreading of diseases and parasites to wild salmon, and hybridization with trout. Since a number of theories have tried to explain why wild salmon stocks have been reduced, the actual effects of farmed salmon on wild salmon are still open to question. Nevertheless, farmed salmon probably has a negative impact on wild salmon stocks.

The main reasons for accidental release of farmed salmon are winter storms, propeller damage, and wear and tear on equipment. In recent years, better management of these problems has led to a reduced number of salmon escapees, which contrasts with the increased number of salmon produced each year. According to the official statistics presented in Figure 4, salmon escapees have been reduced from between 1.5 and 2 million reported in the 1988-1992 period to about 0.5 million reported in 1999 (The Norwegian Directorate of Fisheries.) This indicates not only a relative improvement, but also an absolute fall in the number of escapees. These figures should be treated with caution because they are probably lower than the actual number of escapees. Since escapes of salmon can generate negative publicity and may even lead to lawsuits, salmon farmers have incentives to under-report the actual number of salmon escapees. Farmers may also be unaware of escapes because damage to cages is detected late, or they may not know exactly how many fish are in the cages. However, underreporting is unlikely to affect the main trends. Thus, it is possible to infer an inverted U-shaped relationship between the absolute number of salmon escapees and the growth of Norwegian salmon aquaculture. This implies that salmon farmers have incentives to internalize this problem.

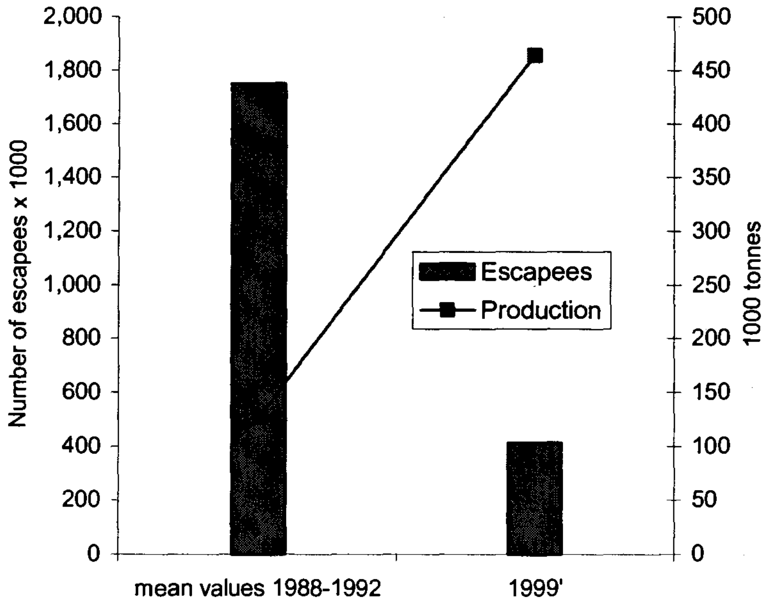

Figure 4. Number of escaped salmon in 1988-1992 and in 1999 compared with production

Source: Directorate of Fisheries

Infection by sea lice is possibly one of the most important factors that reduce the stock of wild salmon. Registrations show that the heaviest infections of wild salmon are limited to areas with a high concentration of salmon farms (Tully, Poole, and Whelan 1993; Tully *et al.* 1993; Grimnes *et al.* 1998). A plausible explanation is that the number of hosts is larger in areas with a high concentration of salmon farms, thus leading to a higher concentration of sea lice in that area. Nevertheless, the connection between fish farming and the reduction of wild salmon stocks generates a great deal of insecurity. Analysis of a small sample of rivers in Scotland and Norway showed no marked reduction from 1987 to the present day in farming-intensive areas (Hansen 1999). However, by comparing 77 different rivers, Sægrov *et al.* (1997) found that the largest reductions of wild salmon occurred in farming-intensive areas.

Sea lice infections and salmon escapes are probably the major remaining environmental problems in salmon farming today. Salmon farmers clearly have an incentive to limit the number of sea lice because of negative feedback effects on productivity and for marketing purposes. This involves the use of chemicals and sea wrasses. However, it is not clear that salmon farmers have an incentive to reduce the number of sea lice to a level that is significantly below the level required by the market. This means that sea lice concentrations in salmon farming areas might be relatively high even if the number of sea lice living on the farmed salmon is at an acceptable level. Thus, it is uncertain whether there has been an inverted U-shaped pattern for the level of sea lice in salmon farming areas. Research on vaccines against sea lice continues, but there has been no breakthrough to date.

Summary and Discussion

This paper has investigated the issue of whether some pollutants have an inverted U-shaped relationship to industry growth. Empirical studies of the EKC hypothesis are typically conducted at the macro level and use economic growth, represented by GDP for example, as the explanatory variable to test for an inverted U-shaped relationship for pollutants. However, for many pollutants, there are indications that the industry level is an interesting one at which to study this relationship, since industries are the main source of many pollutants. Moreover, industry growth seems to play an important role by changing the framework by which firms operate. Industry growth stimulates more investment, and this investment can be channeled towards the development of abatement technologies, thereby increasing the elasticity of substitution between conventional inputs and pollution. This is closely related to the induced innovation hypothesis of Hicks (1932), which states that a change in the relative prices of inputs should induce innovations directed to economizing the use of the input which has become relatively more expensive. Here, the relatively more expensive input is pollution, provided that industry has incentives to internalize it. An empirical test of this relationship is performed, in which the independent variable is industry growth, rather than economic growth. This is used for empirical tests of the EKC hypothesis at the country level. As dependent variables we use measures of pollution, pollution per unit produced and total pollution. This allows us to investigate first if the industry has incentives to reduce pollution, and secondly if they are strong enough to lead to an absolute pollution reduction. Internalization is a pre-condition for industry growth to facilitate the reduction of environmental problems. Therefore, an inverted U-shape pattern of pollution in relation to industry growth will not apply to all environmental problems, since not all industries have incentives to internalize them.

Data from the Norwegian salmon aquaculture industry support the idea that the industry level is an appropriate level at which to study the relationship between changes in environmental quality and growth. The data cover the period from the early 1980s to the end of the 1990s, which was a period of tremendous growth in the Norwegian salmon aquaculture industry. These data provide evidence of inverted U-shaped relationships between environmental indicators and the growth of the Norwegian salmon aquaculture industry. This implies that Norwegian salmon farmers have increased the degree of internalization due to negative feedback effects from pollutants as the industry has expanded. The use of antibiotics and chemicals has been reduced in absolute terms. The number of salmon escapees may have also declined. In the case of sea lice and effluence discharges, results are more uncertain given the lack of data. However, the reduction in the FCR shows that, relative to production volume, organic waste discharges have been reduced, which is important given the substantial increase in salmon production over the last two decades.

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