Norges
Handelshøyskole
Norwegian School of Economics
and Business Administration

Testing for Market Boundaries and Oligopolistic Behaviour: An Application to the European Union Market for Salmon

by

Frode Steen

A dissertation submitted for the degree of dr. oecon.

I

If you think...that anything like a romance is preparing for you, reader, you were never more mistaken. Do you anticipate sentiment, and poetry, and reverie? Do you expect passion, and stimulus, and melodrama? Calm your expectations, reduce them to a lowly standard. Something real, cool and solid lies before you; something unromantic as Monday morning, when all have work wake with the consciousness that they must rise and betake themselves thereto.

Charlotte Brontë: Prelude to Shirley

Preface

Finally, I can start with the beginning! This thesis has been written over a three year period. Except for the academic year 1993/94, when I was a visiting scholar at Department of Economics at Simon Fraser University, I have been at Department of Economics here at NHH. Since August, 1993 my employer has been the Foundation for Research in Economics and Business Administration (SNF). Financial support from the Norwegian Fisheries Research Council and NHH made my stay at Simon Fraser University possible and is gratefully acknowledged.

A thesis project involves quite a few people, and I would like to thank some of them here. Kjell Gunnar Salvanes has been my supervisor. He has shown an interest in my work that has made this project both interesting and challenging. He has read numerous 'preliminary' drafts, and has helped me back on track when it was needed. I would also like to thank the two other members of my dissertation committee, Trond Bjørndal and Curtis Eaton. During my stay at Simon Fraser University, Curtis Eaton was available both for discussion and comments, and helped me clarify my thoughts in an excellent way. He also made my working day very efficient, by borrowing me his office for 8 months. Trond Bjørndal has with his very detailed comments improved the specification of my models, as well as the clarity of my language.

There are several persons who have read and commented on earlier drafts of separate chapters of my thesis (in alphabetic order): Frank Asche (Chapters 1, 2 and 3), Mark Kamstra (Chapter 2), Nicolas Schmitt (Chapter 2 and 3) and Margaret Slade (Chapter 2). Thanks to all of them.

Most of my work has been done here at NHH, and I would like to express my gratitude to the members of Department of Economics. It has been a stimulating environment to write a thesis in, and I have learned (and laughed) a lot during coffee breakes and seminars. This is applicable also for Department of Economics at Simon Fraser University, where I was included as a staff member, and taken well care of.

Last, but most important, my gratitude goes to Kaya, Emil and Nina. Nina for being both patient an encouraging in periods where *my* thesis project has become the *family's* thesis project, Kaya and Emil for showing me what life is all about.

And now—it is Christmas!

Bergen, December, 1994. Frode Steen

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An Overview

Recently there has been a rapid growth in the econometric literature focusing on industry conduct, the existence of market power and various forms of imperfect competition.[1] This is an offspring of a large new literature on oligopoly and game theory. The large number of new theories has made it possible to explain almost every industry observation, and competing theories explain the same observation. As only few results hold across a broad range of model specifications, a need for finding empirical regularities become apparent. As Sutton (1991) puts it, according to the modern theory of oligopoly, "anything can happen", and one may ask whether the theory "in explaining everything has explained nothing"? The new empirical literature addresses this theoretical ambiguity problem, by trying to specify different oligopoly models in an empirical framework, and testing the models on industry data. In particular, one attempts to be able to nest these models in a way that minimises the use of cost and profitability data. This new empirical literature is often referred to as the "new empirical industrial organisation" (NEIO) literature.

Parallel to this new interest in empirical industrial organisation, we have seen a methodological time-series revolution, changing the whole concept of how to deal with dynamic econometric problems. Hitherto the empirical implementations are predominantly found in macro-economic studies. From being unknown concepts to most economists, cointegration, non-stationarity and unit-root testing have become standard concepts, treated in most new econometric textbooks, and part of the economist's everyday vocabulary.[2] However, although time series data is often used also in NEIO studies, the dynamic nature of the markets is mostly neglected.[3]

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[1] Bresnahan (1989) and Geroski (1988) provide a comprehensive review this literature prior to 1988, and Slade (1994) reviews the latest development in this field.

[2] See for instance Cuthberson, Hall, & Taylor (1992), Davidson & MacKinnon (1993), Greene (1993) and Hamilton (1994).

[3] There are some exceptions. Roberts and Samuelson (1988) have analysed the US cigarette industry using a dynamic econometric model, estimating intertemporal conjectural variations. Bernstein (1994) uses a dual approach testing for price-cost margins in the Canadian softwood lumber industry. Finally, using state-space models , Karp and Perloff (1989, 1991), Hall (1990), Reynolds (1986) and Slade (1990) incorporate dynamics by modelling two-period or multi-period games empirically. However, the dynamic modelling in these latter studies are based on dynamic optimisation models.

Since 1980 the international market for salmon has changed considerably due to the development of the farmed salmon industry. This has led to an increased interest in the market structure of this industry.[4] The purpose of the thesis is to undertake an empirical analysis of the European market for salmon, and in particular Norway's role in this market, combining time series techniques with the NEIO framework. In this dissertation, econometric time series techniques are shown to be useful also in empirical industrial organisation, being the econometric framework used throughout the dissertation.

The dissertation consist of four essays; chapters one through four. The analyses are meant to give a more comprehensive understanding of the structure in the European market for salmon. In particular questions about market boundaries, intertemporal changes in competition and market power are addressed. The problem is approached by making use of new data, and analysing these from different perspectives. The market structure in the European salmon market has previously not been addressed as extensively as in this dissertation.

Chapter 1 presents a descriptive survey of the salmon market in the EU. Supply and demand side characteristics are investigated, and factors important to market structure discussed. The supply side for salmon in the EU is shown to be dominated by a few large countries producing farmed salmon. In particular, the market for fresh salmon is found to be concentrated, with Norway and Scotland accounting for 80 to 90% of the market. The organisational and industrial structure provides grounds for treating the producing countries as units, rather than countries consisting of a large number of independent producers. The literature on market structure is shown to be ambiguous, indicating a competitive EU salmon market in the long run, but also providing arguments for Norway and Scotland having some oligopolistic market power in the short run. The seasonal supply pattern of wild caught salmon from North America is shown to be important, suggesting that models allowing for intertemporal price discrimination may be appropriate in the EU salmon market.

Chapter 2 proposes the use of multivariate cointegration tests as a market delineation tool. The problem of stochastic seasonality when employing cointegration tests on seasonal

[4] See for instance Bjørndal & Schwindt (1989), DeVoretz & Salvanes, (1993), Herrmann & Lin, (1988), and Bjørndal & Salvanes, (1992).

data is addressed. This is done by removing seasonal cycles prior to the cointegration tests. Both geographic market boundaries and product space boundaries are tested for. We find evidence for fresh, frozen and smoked salmon to be in the same market. The geographic tests are more ambiguous, suggesting two different geographic markets for frozen salmon in the EU: one single market in France, and the rest of the EU as an aggregated group. The market for fresh salmon is found to be more integrated, i.e., one EU market for fresh salmon.

Chapter 3 presents a cointegration test for intertemporal price discrimination, focusing on the importance of intertemporal changes in competition. The supply of wild-caught fresh Pacific salmon to the EU is constrained during certain periods, as opposed to Norwegian farmed salmon, which is supplied throughout the year. Due to the seasonality in supply and Norway's dominant position with a market share of more than 70%, Norway is claimed to exercise intertemporal price discrimination in this market. The analysis provides some support for the hypothesis that reduced competition negatively affects the stability of the cointegration relations, suggesting a lower interdependence of prices during the periods when the supply of wild-caught Pacific salmon was restricted. However, one is not able to conclude that fresh salmon is excluded from the long-run relationship. Hence, intertemporal changes in competition matter, but not to the extent that Norway is free to set prices on fresh salmon independently of the prices for frozen and smoked salmon. These findings weaken the argument that Norway may have seasonal monopoly power and thus may have exercised intertemporal price discrimination in the market for fresh salmon in the periods where wild-caught salmon was unavailable.

In chapter 4 we propose a dynamic reformulation of the oligopoly model of Bresnahan (1982) and Lau (1982) in an error correction framework. This framework solves both statistical problems generated by short run dynamics in the data and incorporates important dynamic factors such as habit formation from the demand side and adjustment costs for the producer. We also propose a test for separability of the variables involved in the identification of the market power parameter, using the Johansen and Juselius (1990) multivariate cointegration test. To illustrate the model, the French market for fresh salmon is analysed. The results suggest the salmon market to be competitive in the long run, but indicate that Norway has some market power in the short run, a result that has some support in the literature. The empirical implementation shows that the framework is tractable empirically, and that it provides considerably more information than what the simple static version of the Bresnahan-Lau model provides.

In chapter 5 a summary of the dissertation is provided, together with ideas for future research in this area.

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—Part I—

Market Description

"Where all are monopolists...the abstract economists...
would be deprived of their occupation...
There would survive only the empirical school,
flourishing in a chaos congenial to their mentality."
(Edgeworth, 1925, p. 139)

—Chapter 1—

The EU Market for Salmon

1.1. Introduction

Since 1980 the international market for salmon has changed considerably due to the development of the farmed salmon industry. In 1980 farmed salmon represented 1% of the total quantity of salmon (wild-stock landings and farmed salmon), in 1990 farmed salmon represented 27%. The total quantity of salmon produced increased by 89% during this period (Bjørndal & Salvanes, 1992). This has led to an increased interest in the market structure for this industry (Bjørndal & Schwindt, 1989; DeVoretz & Salvanes, 1988; 1993; Herrmann & Lin, 1988a; 1988b Singh, 1988; Bjørndal & Salvanes, 1992).

Norway is the largest producer of farmed salmon, accounting for more than 56% of the world production of farmed (Atlantic and Pacific) salmon on average during the period from 1986 to 1991. Together with Japan and the US, the EU is the most important market for salmon, and Norway exported more than 70% of its production of salmon to the EU during the period from 1988 to 1992. The US, which used to be an important market for Norwegian salmon, in 1990 introduced a 26.1% retaliatory tariff on fresh salmon from Norway.[1] This has made the EU market even more important to Norway.

The aim of this chapter is to give a survey of the EU market for salmon. Important supply and demand characteristics are described. Most of the discussion is based on earlier literature on the salmon market. However, using data from the EU trade statistics, EUROSTAT, the chapter also provides new information on some aspects of the salmon market. In particular factors determining the market structure are discussed, e.g. organisational structure, strategic factors, and intertemporal constraints in supply. The survey will serve as an introduction to the questions that are tried answered in the three following chapters in the dissertation.

The chapter is organised as follows. In section 2, the supply side is analysed. In section 3, a survey of empirical demand studies undertaken in this industry, and important market charactheristics are presented. In section 4, the organisational structure is analysed. The market structure is discussed in section 5. The research agenda for the dissertation is presented in section 6.

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[1] In 1989 Norway exported 13 000 tonnes of salmon to the US; in 1991 only one tenth of this quantity was exported to the US.

1.2. The Supply Side

In all cases where no particular data source is referred to, the numbers presented are based on data from the EU trade statistics—EUROSTAT. The data set contains monthly observations for quantities and values for the period October 1980 to December 1992 (precise variable definitions are given in Appendix A).

1.2.1. The World Production of Salmon

The supply of salmon originates from two sources, farmed and wild caught salmon. Table 1 shows the relative and absolute importance of these.

Table 1

World production of salmon 1980 to 1990.

Year	Wild Caught Salmon (1000 ton)	Farmed Salmon (1000 ton)	Total Production (1000 ton)	Farmed Salmon's share of Total Production
1980	537.4	4.8	542.2	0.9
1981	649.0	11.6	660.6	1.8
1982	557.2	16.5	573.7	2.9
1983	678.7	24.6	703.3	3.5
1984	624.1	32.6	656.7	5.0
1985	793.5	47.1	840.6	5.6
1986	675.0	72.1	747.1	9.7
1987	650.2	84.6	734.8	11.5
1988	612.0	139.4	751.4	18.6
1989	705.0	201.2	906.2	22.2
1990	804.0	290.8	1094.8	26.6
Mean	662.4	84.1	746.5	11.3

Source: Bjørndal & Salvanes, 1992.

Total production of salmon grew considerably from 1980 to 1990, and production of both wild caught and farmed salmon increased.[2] The increase in farmed salmon was considerably higher than the increase in wild caught salmon, but wild salmon still dominates the supply. There are

[2] One of the reasons for the variation in wild caught salmon is stochastic variations in stock size (Bjørndal & Salvanes, 1992).

several species of wild salmon. The relative importance of the five main species of wild salmon is shown in Table 2.[3]

Table 2

Average landings of wild caught salmon 1980 to 1985.

		Average quantity (1000 ton)	Average share of all wild caught salmon
Chinook	(*Oncorhynchus tshawytscha*)	21.2	3.3
Coho	(*Oncorhynchus kisutch*)	35.3	5.6
Sockeye	(*Oncorhynchus nerka*)	135.7	21.4
Pink	(*Oncorhynchus gorbuscha*)	238.0	37.5
Chum	(*Oncorhynchus keta*)	200.9	31.7

Source: Bjørndal, 1990.

Only *chinook* and *coho* are similar in quality with Atlantic farmed salmon (i.e. flesh texture etc.).[4] These two species are also the only Pacific species that are farmed. One of the reasons for the quality differences is the harvesting methods; both *chinook* and *coho* are usually caught with a trolling line, while the other species are caught with fishing net and grill net (the nets can leave unsightly burn marks on the skin, Dupont, 1993). *Sockeye* is also promoted as a substitute to the Atlantic salmon (Bjørndal & Salvanes, 1992). Most of the *sockeye* is exported to Japan. *Chum* and *pink* are mainly used as input in the canning and smoked salmon industry.

The US is the largest supplier of wild caught salmon, accounting for 44% of the total harvest. Japan, the former U.S.S.R. and Canada follow with 28, 16 and 12%, respectively (Bjørndal, 1990).[5]

Atlantic salmon dominates in the supply of farmed salmon, representing 82% of farmed salmon production in 1990.[6] Farmed Pacific salmon is mainly consumed outside Europe. Norway accounted for between 61 and 75% of the Atlantic salmon production in the period from 1986-91, while the second largest producer, Scotland, supplied between 16 and 19% of the production in this period.

[3]The sixth species, cherry (*Oncorhynchus masuo*) is negligible compared to the five main species, accounting for only 0.6% of total landings of wild caught salmon on average from 1980 to 1985.

[4] The shares of chinook and coho are relatively stable also after 1985. In the period from1986 to 1988, they accounted for between 7.5 and 9% of wild caught salmon landings (DeVoretz & Salvanes, 1993).

[5]All Japanese salmon is consumed in Japan. Japan is the world's largest consumer of salmon.

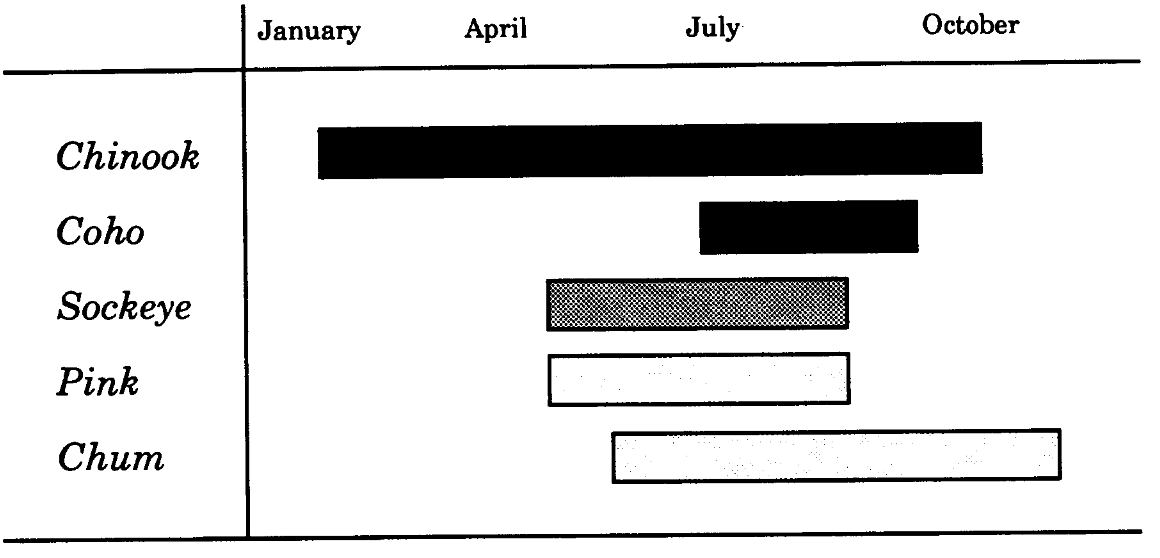
[6]In 1990 238 800 tonnes of Atlantic salmon and 52 000 tonnes of Pacific salmon were farmed(a total of 290 800 tonnes—the figure for 1990 in the third column in Table 1) (Bjørndal & Salvanes, 1992).

1.2.2. Supply Seasonality

Wild salmon is caught mainly in the two last quarters of the year as opposed to farmed salmon, which is supplied all year. In Figure 1 the main harvesting seasons for wild salmon are shown (Holmefjord, 1988).

Figure 1

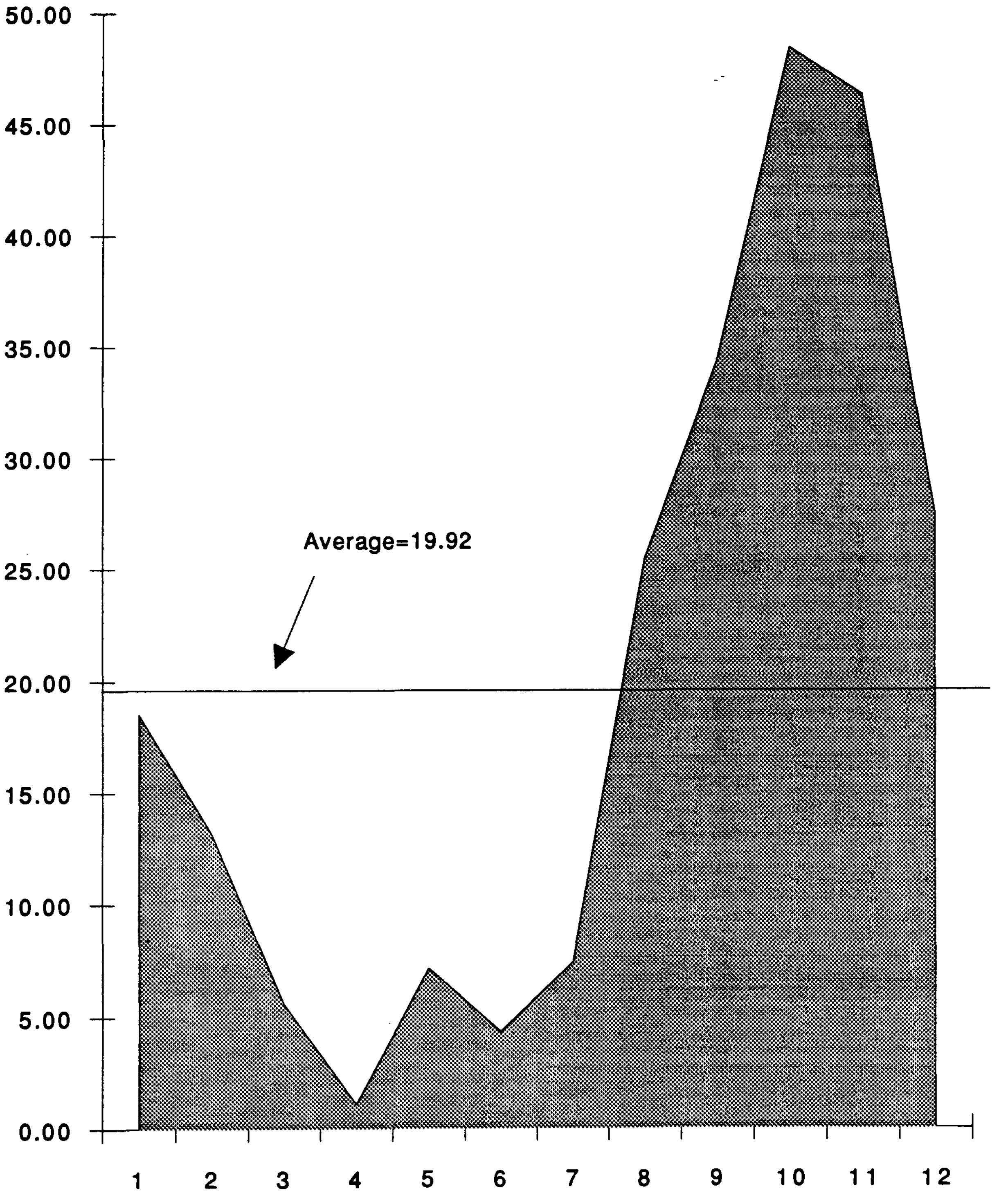
Main harvesting seasons wild caught salmon.



Chinook and *coho* are actually landed all year, but only on a very small scale outside the seasons. Hence, as Figure 1 indicates, most of the harvest takes place in the fall. To get a more precise picture of the North American supply pattern, the monthly averages of fresh Pacific salmon exported to the EU from the US and Canada from 1981 to 1992 are investigated. In Figure 2 this average distribution is drawn. A clear pattern is visible. Exports in January and the last five months of the year are all substantially higher than the rest of the year. When comparing each month's average to the year's average, the period from August to December is above, and January

Figure 2

North-American monthly export distribution of fresh Pacific salmon to the EU, from 1981 to 1992, (in tonnes).



is approximately at the average.[7] When investigating the supply pattern for the US and Canada individually, the picture is the same. The late fall peak corresponds with the period for the salmon run. When looking at January and the five last months' share of yearly supply, 83.8% of the North American salmon (as calculated as the 12 year average) is supplied to the EU during this period. The individual supply figures for the high-competition periods for the US and Canada are 83.6 and 84.6, respectively. The monthly averages are shown in Table 3.

Table 3

Monthly averages of fresh Pacific salmon exported to the EU from the US and Canada, 1981 to 1992.

	Canada (tonnes)	US (tonnes)	Canada & US (tonnes)
January	3.50	15.00	18.50
February	1.25	11.92	13.17
March	0.17	5.42	5.58
April	0.25	0.83	1.08
May	0.08	7.08	7.17
June	1.17	3.17	4.33
July	2.83	4.58	7.42
August	5.58	19.83	25.42
September	5.00	29.33	34.33
October	10.58	37.75	48.33
November	2.50	43.75	46.25
December	4.50	23.00	27.50
Average	3.12	16.81	19.92

Source: EUROSTAT

The strong seasonality in North American supplies is not solely supply side driven. Also demand shifts in accordance to seasons. In particular in the last quarter demand shifts outwards due to the Christmas celebration. However, as will be shown in the next section, the demand shift is not sufficient to explain the strong seasonality in North American supplies.

Even though the US and Canada have small market shares of fresh salmon in the EU (see Table 7), their production (capacity) may discipline the other suppliers, and thus be important to the level of competition in the EU in the last two quarters. If the price of fresh salmon in Europe

[7] The reason that January is so high in this data is probably that there is a certain registration delay in EUROSTAT's database.

reaches a high enough level, they have the capacity to supply large amounts of high quality Pacific salmon. The US and Canada have a considerable export of salmon. Most of their export of fresh salmon goes to Japan. In 1986, 86% of the value of the US's export of fresh and frozen salmon came from export to Japan (Wessells & Wilen, 1993). However, if the price level in Europe increased sufficiently, the industry would find it profitable to increase the supplies to Europe.

During the period from 1983 to 1987, total yearly EU consumption of fresh salmon amounted to 41% of total yearly landings of *coho* and *chinook* on average.[8] If one accounts for the supply pattern, where most of the salmon is caught during the salmon run, the US and Canada could have supplied the entire EU market for fresh salmon in this period in all of these five years.[9] However, outside the salmon run period, the North American capacity is severely limited. Hence, farmed salmon is practically 'alone' in the EU market for fresh salmon in the two first quarters.

Considerable quantities of salmon are frozen and stored in the US and Canada, and are thus supplied also outside the season. Estimates of cross-price elasticities between fresh and North American wild caught frozen salmon indicate that the two products are imperfect substitutes (see next section). This may of course reduce the importance of the supply seasonality to the competition level in the fresh market. However, the overall majority of frozen North American salmon is bought by the smoked salmon industry, as opposed to fresh farmed salmon that is predominantly marketed as fresh (Bjorndal, 1990; Monfort, 1988). Fresh North American salmon is on the other hand mainly sold in the exclusive up-scale 'white tablecloth' restaurant market, and is thus a competitor to the high quality fresh Atlantic salmon.

Another aspect is transportation capacity and transportation costs. For the US and Canada to supply fresh salmon to the EU they must send the fish by air freight which is considerably more expensive than the trailer freight used by European producers, thereby reducing the competitiveness of wild caught salmon in the EU fresh salmon market.[10]

[8]This may also be seen when combining the figures in Table 1 and Table 2.

[9]Even though a substantial quantity of *chinnok* and *coho* is consumed domestically, this argument applies during the salmon run period.

[10]The air freight packing cost is more than twice the trailer freight packing costs, the transport itself is more than five times as expensive by air as by trailer (Holmefjord, 1988).

1.2.3. The Products

Norway is the most important supplier of salmon to the EU, followed by the US, Canada and Scotland. The three main salmon products are fresh, frozen and smoked salmon, representing more than 99% of the salmon market in EU.[11]

The quantities of fresh, frozen and smoked salmon have increased considerably in the analysed period; their relative and absolute importance is shown in Table 4, and drawn in Figure 3.

Table 4

Quantities of all salmon supplied to the EU from 1981 to 1992 (in tonnes).

	Fresh	Frozen	Smoked	Total
1981	6110	30346	1869	38325
1983	11402	34185	2726	48313
1985	19722	36164	3871	59757
1987	38737	45459	6266	90462
1989	83870	34883	8231	126984
1990	105287	48912	9040	163239
1991	116050	67140	11312	194502
1992	137233	64248	12403	213884

Source: EUROSTAT

In particular, the quantity of fresh salmon has increased. From representing only one fifth of the quantity of frozen in 1981, the amount of fresh salmon amounts to twice that of frozen salmon in 1992.[12] The second highest increase (relative) is for smoked salmon, and the 'lowest' (112%) for frozen salmon.

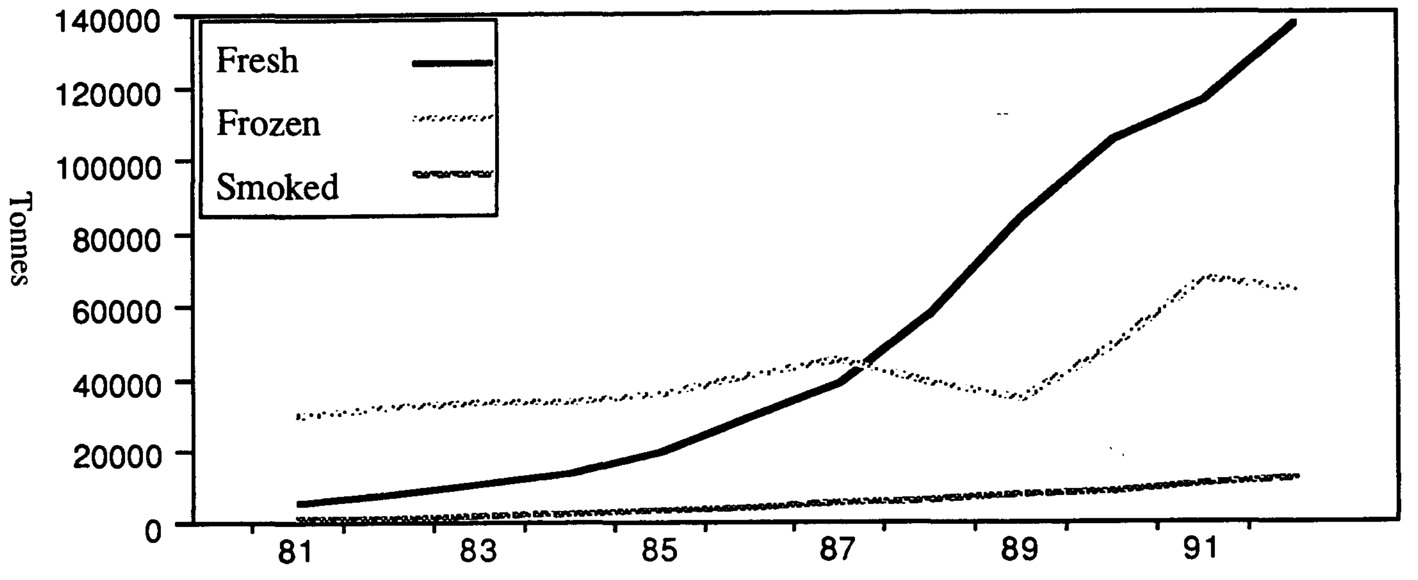
France is the most important market for salmon in the EU. France represents between 17 and 27% of the EU market for smoked salmon in terms of imports the period from 1981 to 1992. Using figures for total consumption of smoked salmon in France for the period from 1981 to 1992, the

[11]The remaining products consists basically of salted salmon.

[12]The Norwegian market share for fresh and frozen salmon together was higher than 60% in all of the last four years 1989 to 1992. The average market share for frozen salmon alone was only 45% in this period.

Figure 3

Yearly quantities of imported fresh, frozen and smoked salmon in the EU from 1980 to 1992.



increase in quantity consumed is slightly lower then the increase in imports.[13] This indicates that the outside suppliers have gained market shares relative to the domestic smoked salmon industry over the analysed period.[14]

Before 1989 the quantity of fresh salmon increased by an average 35% yearly; after 1989 the average growth was 18%. For frozen salmon, the yearly average growth before 1989 was only 2%, and the average growth after 1989 was 24%.[15] This shift is mainly due to the Norwegian freezing program that started in early 1990. At that time a huge amount of salmon was frozen in Norway to reduce the fresh quantity supplied to the market and thus stabilise the declining prices of fresh salmon. Salmon that was earlier sold as fresh now arrived in the market as frozen (see section 4 for a more fully treatment of the freezing program).

[13]The increase in imports for the period from 1981 to 1992 is 564%, the corresponding French consumption figure is 499%.

[14]When looking at the French imports this tendency is even stronger, the smoked salmon import increased with nearly 800% over the period from 1981 to 1992.

[15]From 1987 to 1988 and 1988 to 1989 the yearly growth rates for frozen were negative; -14 and -10%, respectively. From 1989 to 1990 and 1990 to 1991 they were as high as 40 and 37 %, respectively.

There has been a shift in consumption from frozen salmon to fresh salmon during the period in question. This is mainly due to the increase in farmed output, and the farmer's ability to deliver high quality fresh salmon year round.[16] The import of smoked salmon shows a stable increase. The import shares for fresh, frozen and smoked salmon are shown in Table 5.

Table 5

Imported fresh, frozen and smoked salmon's market shares (in percentage) in the EU based on FOB value.

	Fresh	Frozen	Smoked
1981	17.8	69.8	12.4
1983	26.5	60.3	13.2
1985	36.1	49.2	14.6
1987	44.5	37.9	17.5
1989	58.4	23.4	18.2
1992	60.2	23.3	16.5
Mean	41.4	43.0	15.5

Source: EUROSTAT

Since these figures do not include the EU's own production of smoked salmon, they underestimate the relative importance of smoked salmon.

In particular France has a large smoked salmon industry. Of the total quantity of smoked salmon consumed in France, between 70 and 80% is domestically produced (Monfort, 1992; Reintz *et al.* 1992; 1994).[17] In Table 6 we have presented French consumption and import of smoked salmon for the period from 1981 to 1992.

[16]The landings of wild caught salmon have also increased, and in particular in the last part of the period (see Table 1).

[17]France is also the largest importer of smoked salmon in the EU. In 1989 the French import amunted to 27% of the EU import of smoked salmon.

Table 6

French consumption and import of smoked salmon for the period from 1981 to 1992 (in tonnes)./a

	Consumption	Import	Import Share
1981	1900	309	0.16
1983	2390	529	0.22
1985	2360	764	0.32
1986	2940	1012	0.34
1987	4200	1281	0.31
1989	6100	2304	0.38
1990	7380	2162	0.29
1991	9860	2319	0.24
1992	11390	2738	0.24

Source: 1981 to 1986, Monfort, 1988, Household consumption of smoked salmon. Monfort does not specify whether this represents all of the market or only parts.
1987 to 1992, The Export Council of Norway, Paris, André Akse. All sales in the super/hypermarket segment.

a/Since the consumption figures are collected from two different sources, one should be careful with the interpretation. Actually, when looking at the consumption figures in Shaw and Curry (1989) their estimate of the 1989 consumption in France is 18 458 tonnes, indicating an export share of only 0.07. However, their figure does not correspond to other and newer studies.

1.2.4. The Producers

The shares of all salmon imported from 1981-92 are shown in Table 7.[18] Aggregate market shares of the US and Canada declined during this period, while Norway and Scotland have gained shares. The total quantity increased more than 400% during this period. In particular Norway's share the frozen salmon market increased. The increase in the Scottish aggregate market share is mainly explained by a doubling of the market share for smoked salmon from 11% in 1981 to 19% in 1992. Norway has increased its market share for smoked salmon too, but accounts for only about 5% of the EU imports in the last part of this period (1989-1992).[19]

The US and Canada's shares for smoked salmon are below 1%. The market shares for all salmon are shown in Figure 3. Since the market shares are based on imports, the shares do not mirror the actual market situation in the smoked salmon marked. Most of the EU countries have

[18]All shares are based on values. There is no noteworthy difference in using market shares based on quantities.
[19]Norway faces significantly higher tariffs in the EU for smoked salmon than for frozen and fresh salmon. In 1991 the tariff for smoked was 13%, for frozen 2.5% and for fresh 2% (Bjørndal & Salvanes, 1992).

Table 7

Market shares for all salmon (wild caught and farmed) in the EU, for Norway, Scotland, the US, and Canada 1981 to 1992 based on FOB values.

	Norway	Scotland	US	Canada	Rest of world
			Fresh		
1981	74.0	10.8	0.1	0.1	14.8
1983	77.2	8.4	0.5	0.2	13.7
1985	69.5	11.0	0.1	0.1	19.0
1987	69.6	9.4	0.1	0.01	20.9
1989	70.9	10.9	0.7	0.03	17.5
1992	68.1	7.5	0.1	0.02	20.0
			Frozen		
1981	9.5	0.6	40.3	34.0	15.6
1983	13.1	0.8	37.5	36.7	11.9
1985	11.6	0.9	40.6	30.2	16.7
1987	11.9	1.4	40.5	28.4	17.8
1989	38.7	1.0	23.8	18.5	18.1
1990	50.8	1.3	20.9	12.6	14.4
1991	50.4	0.9	15.8	8.6	24.3
1992	39.3	2.0	21.1	9.5	28.2
			Smoked[a]		
1981	2.8	11.0	0.1	1.3	84.8
1983	4.0	9.2	0.1	0.2	86.6
1985	4.1	9.8	0.03	0.5	85.7
1987	5.5	13.7	0.5	0.7	79.7
1989	7.8	17.4	0.1	0.4	74.2
1992	4.4	18.7	0.05	0.3	76.5
			All salmon		
1981	20.1	3.7	28.2	23.9	24.0
1983	28.9	3.9	22.7	22.2	22.2
1985	31.5	5.8	20.1	15.0	27.6
1987	36.5	7.1	15.5	10.9	30.0
1989	51.9	9.8	6.0	4.4	27.9
1992	50.9	8.0	5.0	2.3	33.8

Source: EUROSTAT

[a]The EU countries also produce considerable quantities of smoked salmon domestically.

a considerable domestic production, e.g. the discussion of France. Hence, when for instance Scotland in 1992 had a market share of imports of 19% they had less than half of this share of the EU market for smoked salmon.

Figure 4

Yearly market shares for Norway, Scotland, US and Canada in the EU from 1981 to 1992—All salmon.

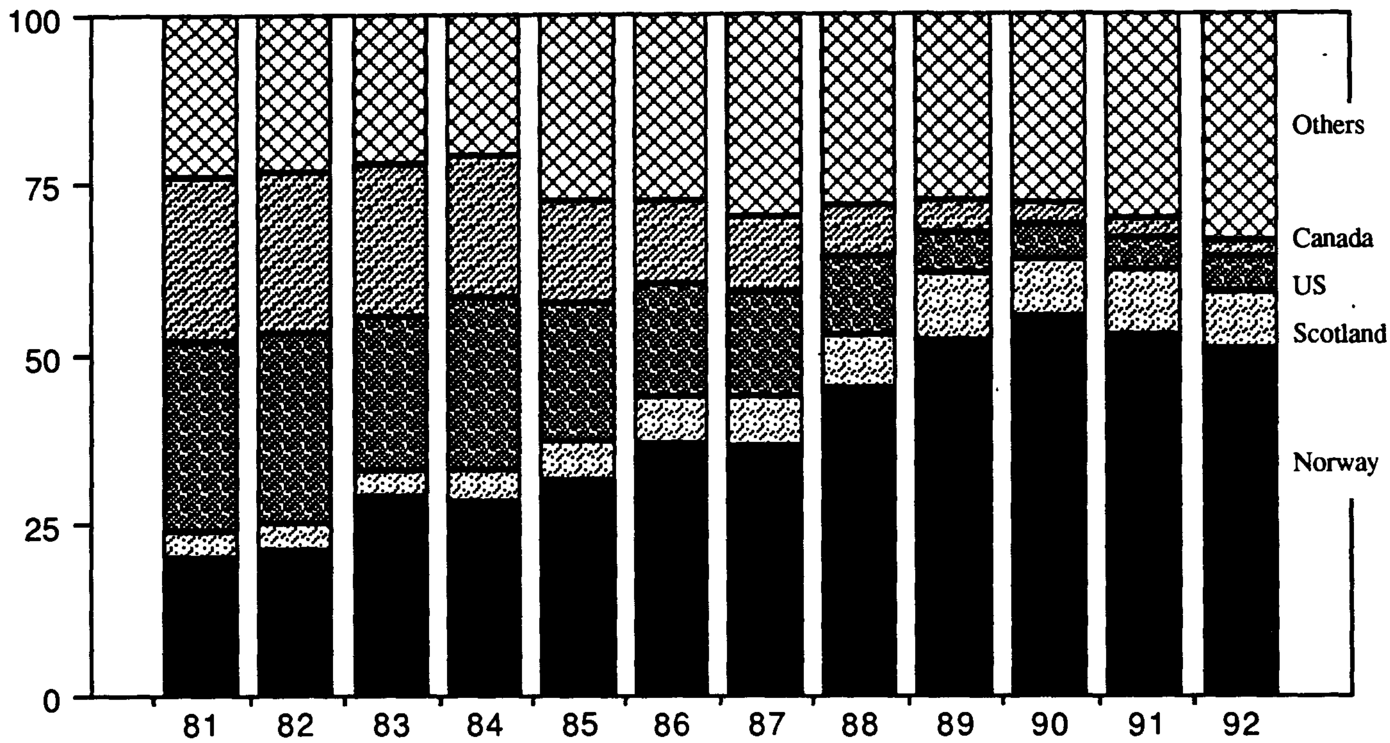
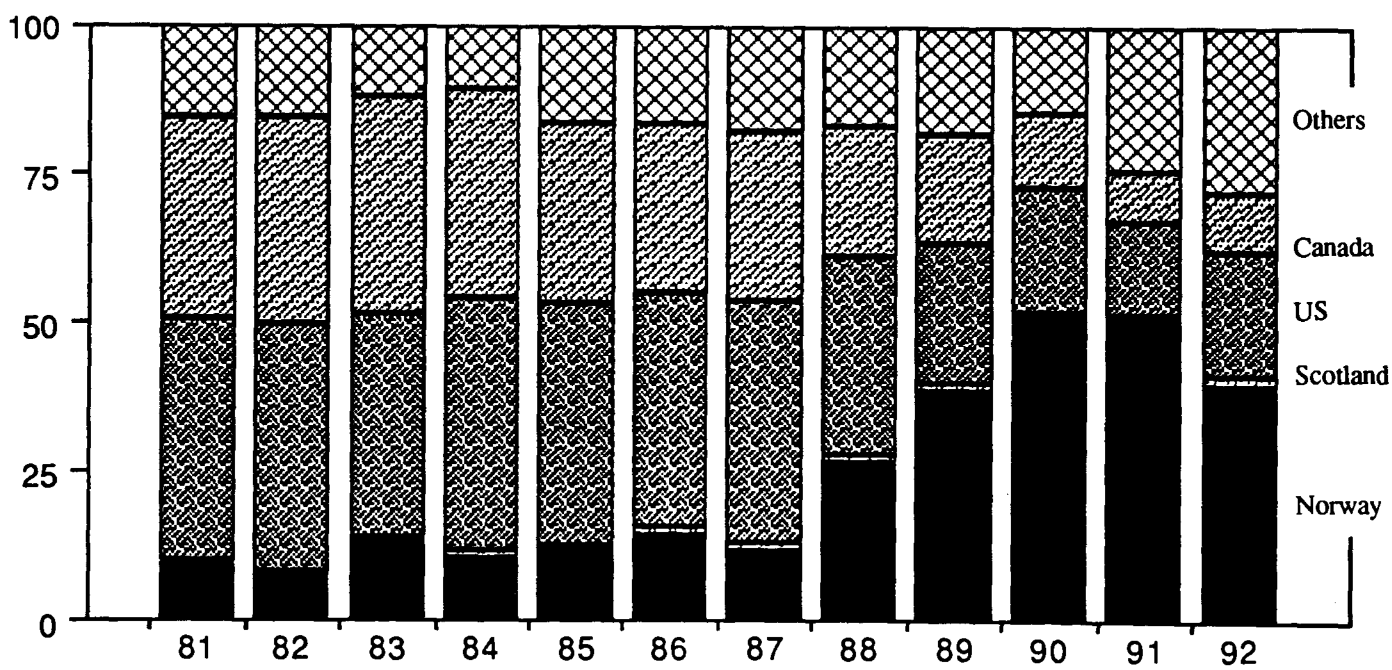


Figure 5

Yearly market shares for Norway, Scotland, US and Canada in the EU from 1981 to 1992—Frozen salmon.

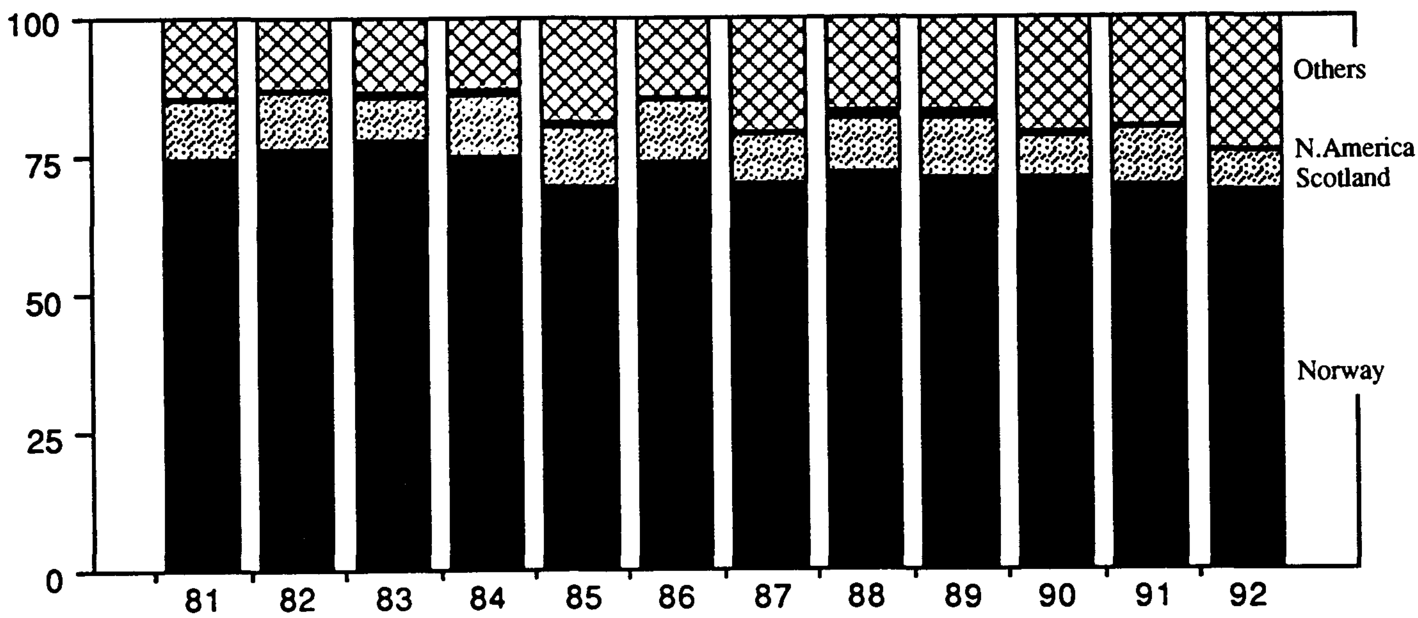


Norway has gained market share for frozen salmon at the expense of the US and Canada, who were dominant earlier. In the period from 1981 to 1992 these three suppliers accounted on average for more than 80% of the EU market. From being the smallest supplier of the three in 1981, Norway grew to become bigger than the US and Canada combined in 1992. Norway's average market share for the period from 1981 to 1984 was 10 %, and the total for the US and Canada was 76%. For the 1988 to 1992 period these average shares have changed to 45% and 33%, respectively (see Table 7).[20] The market shares for frozen salmon are presented in Figure 5.

Norway has been the main supplier of fresh salmon throughout the period, with an average market share of 72%. The second biggest producer of fresh salmon is Scotland with an average share of 10%. The shares for fresh salmon are given in Figure 6.

Figure 6

Yearly market shares for Norway, Scotland, US and Canada in the EU from 1981 to 1992—Fresh salmon.



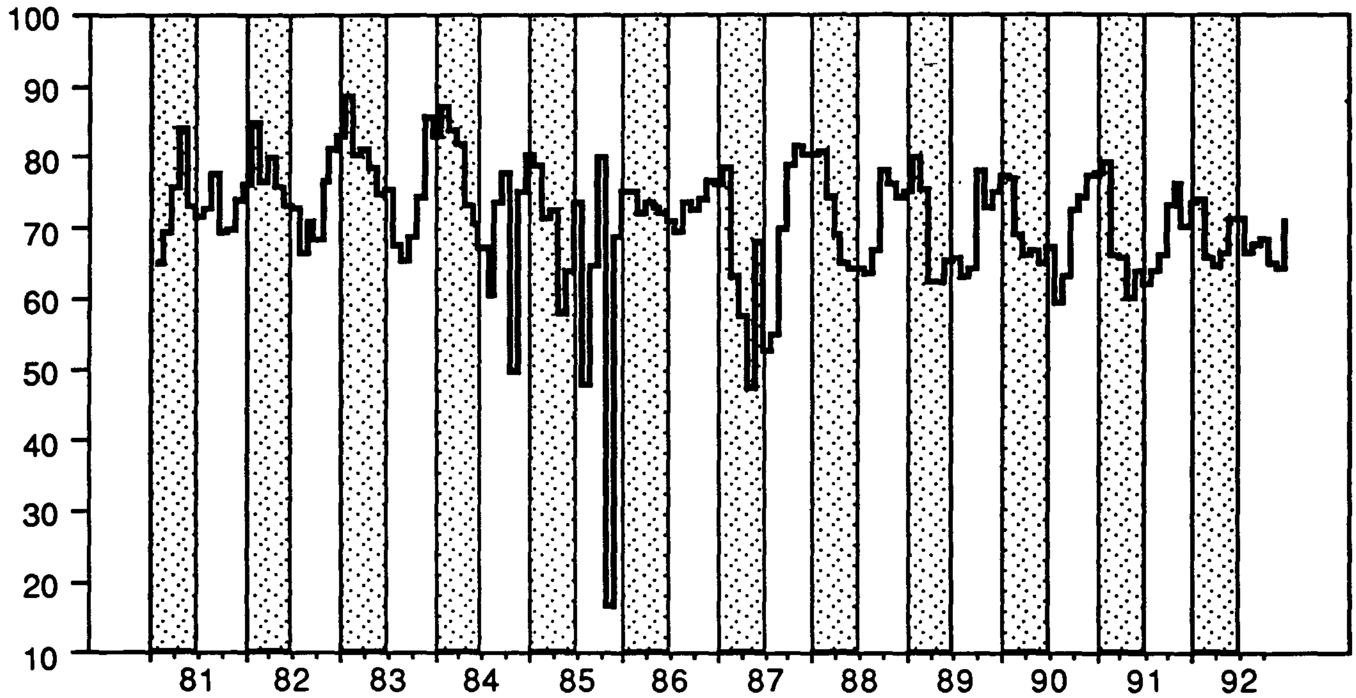
When one looks at the seasonal pattern in market shares, the EU market for fresh salmon is even more concentrated. If we investigate the monthly market shares for fresh salmon, it is apparent

[20]The explanation for the intermediate increase in Norway's frozen market share in 1990 and 1991 is the Norwegian freezing program introduced in late 1989 (see below).

that Norway alone has more than 90% of the market in some months. Norway's seasonal market shares are shown in Figure 7.

Figure 7

Monthly market shares for Norway in the EU from 1981 to 1992—Fresh salmon (the shaded areas are the first six months of the year).



Norway dominates the market for both fresh and frozen salmon, but Norway's competitors have different roles in these segments. The US and Canada are the main competitors in the frozen market segment, where Scotland is very small. The opposite is true for fresh salmon, thus, it seems as if Norway has more flexibility, facing different main competitors in the two segments. However, only the US and Canada face intertemporal constraints in the form of biologically determined harvesting periods, and higher transportation costs in the supply of fresh salmon to the EU. Scotland may supply both fresh and frozen salmon all year round without these constraints.

The remaining producers have also grown during this period. The main producers in this group are the Faroe Islands, Chile, Ireland and Iceland, all of whom supply farmed salmon. In 1991, the Faroe Islands, Chile, Ireland and Iceland produced 7.7, 3.1, 4.2 and 1.9% of the farmed salmon, respectively (Bjørndal & Salvanes, 1992).

1.2.5. The Cost Structure

There exist several cost studies of the Norwegian salmon industry, most of which are at firm level (Bjørndal & Salvanes, 1991; Salvanes, 1989; Salvanes, 1992; Salvanes & Tveterås, 1992). The main cost components are feed, smolt, labour and capital. During the period from 1986 to 1990 these four components represented between 73.9 and 83.8% of total costs.[21] All of the studies cited find the average firm to be described by increasing returns to scale. In particular the earlier studies reported high returns to scale elasticities. During the 1982 to 1990 period the production volume for the average firm increased substantially.[22] Hence, as the quantity produced increased, scale advantages were exploited.

Salvanes and Tveterås (1992) found substantial variation in productivity among firms, but they were not able to find any regional or otherwise systematic pattern in the variation. When choosing firms according to their cost/output ratio, and estimating cost functions for the most efficient quartile of firms, they found constant returns to scale for the average firm. Thus, the most efficient firms seem to have exploited the scale advantages. The upper quartile of firms typically produced higher quantities than the average firm,.

There exist very few studies making cost comparisons between countries. Needham (1991) undertakes a study of average production costs per tonnes farmed salmon in Norway, Scotland, Canada and Chile in 1989. The results are shown in Table 8.

Table 8

Average production costs (FOB) per tonnes salmon in 1989 (in Canadian dollars, 1989 prices).

	Norway	Scotland		Canada		Chile
		Mainland	Shetland	East	West	
Cost in CAD	5000	8000	6500	6400	6900	5000

Source; Needham, 1991.

[21] Most of the empirical studies apply flexible translog cost functions, using feed, labour and capital as inputs. All three inputs are typically found to be substitutes. Due to data limitations smolts are left out of the analyses, implying an assumption of weak separability between smolts and the three analysed input factors (Salvanes, 1989).

[22] In 1982 the average firm produced 92.8 tonnes, in 1990 it produced 233.5 tonnes.

Norway and Chile are found to be most efficient, with the same production costs. Scotland has between 30 and 60% higher costs than Norway and Chile, and Canada has between 28 and 38% higher costs.[23]

The EU commission analysed the cost structure in 41 Norwegian salmon farms and 22 Scottish salmon farms. The results showed that the average production cost was significantly higher in Scotland.[24] The Scottish average cost was found to be 56% higher than the Norwegian average cost[25] Thus, it seems that Norway has cost advantages compared to its competitors.[26]

In 1989 a lot of farms were unprofitable due to the low prices. The freezing program initiated by the Norwegian FFSO delayed the effect of these problems somewhat by stabilising the prices. Furthermore, the program acted as an artificial domestic market where the Norwegian farmers sold their frozen salmon at minimum prices (see section 4). However, after the failure of FFSO, a considerable number of Norwegian farmers went bankrupt or were bought out. This restructuring of the industry has made it more efficient, and since 1992 the industry has been profitable.

1.3. The Demand Side

Several empirical demand studies have been undertaken in this industry. Some of these demand studies are summarised in Table 9. The differences in results could be ascribed to differences in model specification, aggregation level, time horizon and time period analysed.

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[23]Shaw and Gabbott (1990) found the average production costs per tonnes salmon on the west coast of Canada (British Columbia) to vary between 6850 and 7280 CAD (1989), according to product type looked at, i.e. regular age *coho*, accelerated *coho*, regular *chinook* etc.

[24]These figures are taken from Kontali A/S (1991) *'Produksjonsprognose av europeisk oppdrettslaks'*, Kristiansund.

[25]The Scottish average cost was found to be 37.48 NOK per kilo; the Norwegian average cost was calculated as 24.08 NOK (1989 prices). If one compares these numbers with Needham (1991) one finds that they approximately correspond for Scotland, indicating a Scottish average price per ton in 1989 in the interval between CAD 6500 and 8000. For Norway the EU figures indicate an even lower average production cost than what Needham found.

[26]In the Norwegian Fishery directorate's profitability analysis of the Norwegian farming industry for 1989 the average cost of producing one kilo of salmon was found to vary between 31.44 and 33.09 NOK on average according to farm size. Hence, a cost level between 12 to 16% lower then the Scottish cost level. The average cost for the 15 most efficient farms was as low as 19.41 NOK.

Table 9

Survey of demand studies on the EU and countries in the EU [a)]

Market	Time Horizon	Data Period	Own-price Elasticity	Cross-price Elasticity	Income Elasticity	Study
EU	SR	01:83-12.88	-2.14	1.12	2.14	(DeVoretz & Salvanes,1993)
EU	SR	01:83-03:87	-1.83	0.37	2.73	(Herrmann & Lin, 1988b)
France	SR	01:81-06:90	-1.06	1.07	1.88	(Bjørndal, *et al.*, 1992)
	LR		-1.30	1.31	2.30	
France	SR	01:81-06:90	-1.35 [0.19]	1.16 [0.29]	5.69 [0.83]	(Andreassen, 1991)
Spain	SR	01:85-12:89	-1.09	-	-	(Bjørndal, *et al.*, 1991)
	LR		-2.11	-	-	

a)Standard deviation in parentheses, SR: Short run, LR: Long run.

All the studies indicate an elastic demand for salmon. The aggregated EU market is found to be more elastic than the disaggregated country markets. Analyses of the world market find that this is even more elastic, and the US market is generally found to be more elastic than the EU market (DeVoretz & Salvanes, 1993; Bjørndal, Gordon, & Singh, 1992; Herrmann & Lin, 1988a; 1988b) . Studies that have been undertaken for Japan conclude that demand in the Japanese market is price-inelastic (Kikuchi, Johnston, & Shin, 1987; Herrmann, Mittelhammer & Lin, 1992). However, Herrmann *et al.* found own-price elasticities close to *one* , (i.e., in the interval -0.944 to -0.922).

All the long run elasticities are found to be higher in absolute value than the short run elasticities. This is reasonable since consumers usually do not react to price and income changes immediately, but adjust the consumption pattern more in the long run.

All demand analyses presented in Table 7 are based on data at the exporter-importer level, i.e. they represent derived demand for salmon. Little, if anything, is known about demand elasticities at the point of final consumption (Bjørndal, 1990). Further, a problem with the earliest of these studies is the immature nature of the salmon aquaculture industry during the time period investigated. For instance, Herrmann and Lin (1988b) use lagged quantities in the supply equations to capture possible demand shifts. In a rapidly growing market this is insufficient to capture the decisions which go into production of farmed salmon, such as varying prices on inputs, changing technology and growing capital stock (Wessells & Anderson, 1992).

Another aspect is the aggregation problem. During the last 10 years the demand for salmon has expanded and the product has changed from a virtually exclusive up-scale 'white tablecloth' restaurant commodity, to a product sold also in other restaurants and supermarkets. Each of these market segments is likely to have a different demand elasticity, which is obscured in an aggregated model.

The products chosen to represent the substitutes in the demand studies for farmed salmon are fresh or fresh/frozen wild salmon from the US and Canada (*chinook* and *coho*), or high valued white-fish species. The estimated cross-price elasticities indicate that wild and farmed salmon are substitutes. The lower the substitutability, the higher the possibility to discriminate between the two products.

An interesting question is how close substitutes wild and farmed salmon are, i.e., whether they are to be regarded as the same products competing in the same market. This question is not empirically tested in the literature. However, the cross-price elasticities indicate imperfect substitutability between wild and farmed salmon.[27]

The same question about substitutability applies for the relationship between frozen and fresh salmon. It is only if fresh and frozen salmon are imperfect substitutes that the intertemporal restrictions in the North American supply would have an effect on the degree of competition in the fresh salmon market, i.e., as opposed to fresh North American salmon, frozen salmon can be delivered all year round. In Herrmann & Lin's (1988b) study, they found frozen chinook to be a substitute for fresh Norwegian salmon. Their results suggest imperfect substitutability with a cross-price elasticity of 0.37 (see Table 8); thus leaving the question of the importance of intertemporal supply restrictions open. When discussing potential monopoly/oligopoly power, these substitutability questions are important to answer. The higher the substitutability, the larger the market, and the smaller the opportunity for a monopolist or an oligopolist to price discriminate.

The income elasticities are all around two or higher. Hence, salmon could be regarded as a

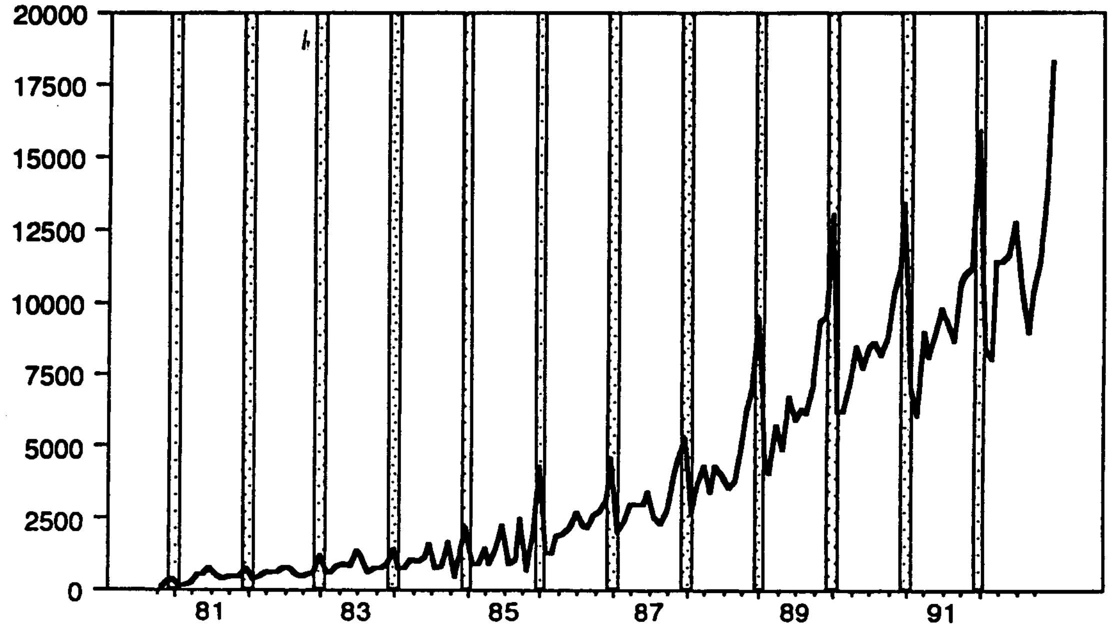
[27]Herrmann (1990) also found some evidence for substitutability between farmed Atlantic salmon and Pacific salmon species (*chinook*, *coho* and *sockeye*) in his aggregated demand study for the EU.

luxury product.

Seasonal variation in demand is found to be important in several of these studies (Bjørndal, *et al.*, 1992; DeVoretz & Salvanes, 1993; Herrmann & Lin, 1988a; 1988b; Herrmann, *et al.*, 1992). In Figure 8 the monthly quantities for fresh salmon is drawn.

Figure 8

Monthly quantities of fresh salmon in the EU from 1981 to 1992 (the shaded areas are December and January each year).



Salmon is commonly consumed as part of the Christmas celebration; hence the peaks in December every year (the shaded area in Figure 8 represents December and January). There is a smaller peak in the middle of the summer, too. One of the reasons for this is the French tradition of having both religious and family celebrations in May/June (France accounts for about 50% of the EU consumption). Approximately 50% of fresh salmon is sold to the processing industry and smoked, hence determining an important factor in the fresh salmon seasonality (Monfort, 1988; Shaw & Gabbott, 1990; Shaw & Curry, 1989). Imported smoked salmon peaks even more distinctly than fresh salmon in December, with 4 to 5 times the average monthly consumption in this month. These figures actually under-estimate the smoked salmon seasonality. When accounting also for domestic production, even more salmon is consumed in December. Monfort (1988) looked at household consumption of smoked salmon in 1986, dividing 1986 into 13 four week periods. During the last four weeks, 51% of the yearly production of smoked salmon was consumed. This corresponds to more recent figures where Reintz et. al. (1994) found the December consumption to represent 45% of the yearly production. The 1986 four week distribution in France is drawn in Figure 9. The peak in the fourth period corresponds to the traditional fisheries product consumption at Easter.

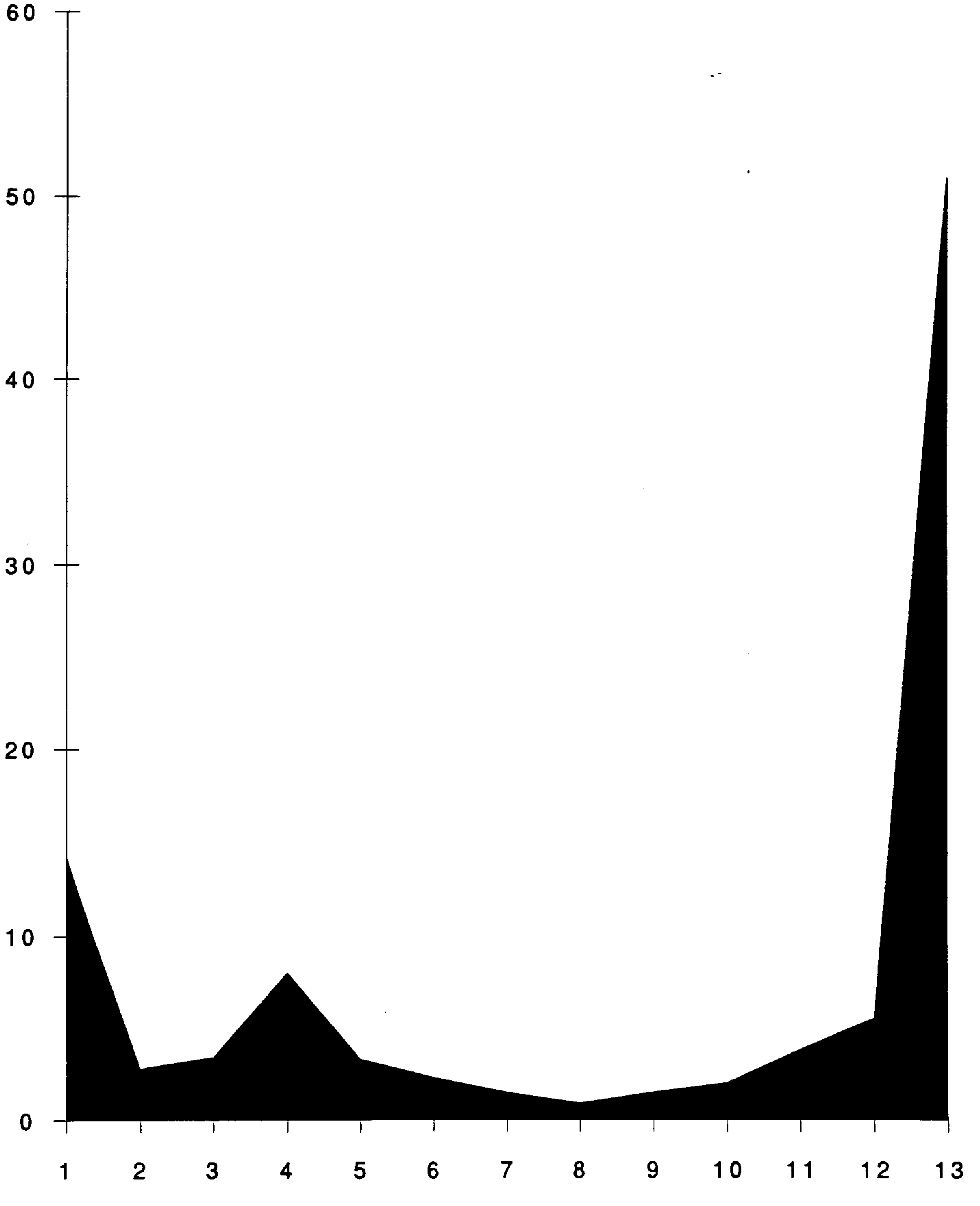
The patterns for frozen salmon is similar. Since the overal majority of frozen salmon is used as input in the smoked salmon industry, the smoked salmon consumption is the main determinant of the frozen salmon seasonality (Monfort, 1988; Shaw & Gabbott, 1990; Shaw & Curry, 1989). To reduce the seasonal pattern of activity some smokers predominantly buy frozen fish (Monfort, 1988). The seasonal highs for frozen salmon come two months earlier in the fall, in October, thus mirroring the smoking process.

In section 2 we discussed the North American seasonality in supplies. The demand shifts outwards due to the European Christmas celebration, and may thus explain some of the increase in supplies. The average share of imports of all fresh salmon in the EU in August through January for the period from 1981 to 1992 is 55%. This figure is a reasonable approximation to the seasonality in the consumption of fresh salmon. The North American supply during the period from August through January for this period is 83.8%. Hence, the outward shift in demand in this period cannot explain the strong seasonality in the North American supplies.

France is the most important salmon market in the EU. The French *per capita* fish consumption is considerably higher then the EU average. The French *per capita* consumption on average of all salmon for the period from 1985 to 1987 was 0.677 kilos, the corresponding EU average was .232 (Bjørndal *et al.* 1990). The French market is also different in other aspects. They have the largest salmon processing industry, and in particular, the largest smoked salmon industry. Their distribution system is more dominated by the super/hypermarket segment in terms of sales. In 1987, 68% of all smoked salmon was sold in this segment (Monfort, 1988). There has been a change towards more super/hypermarket sales. In 1980 21% of all fish products were sold

Figure 9

The four-week distribution of household consumption of smoked salmon in France, 1986 (Monfort, 1988)

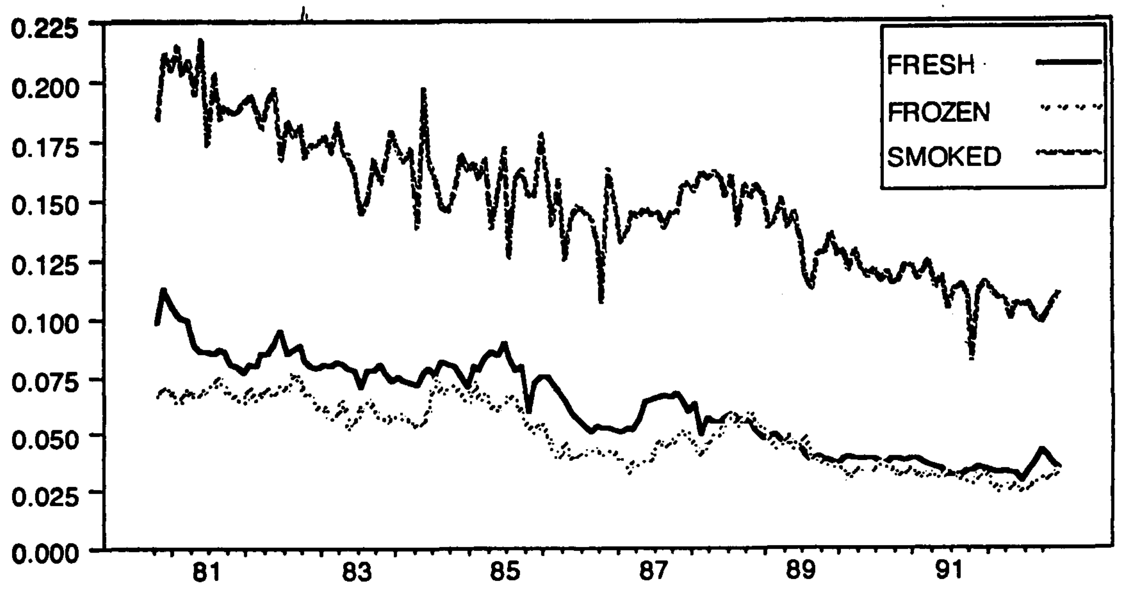


in this segment, in 1989 the share had increased to 40%. At the same time the share of the specialised fish stores was reduced from 40 to 30% (Andreassen, 1991). In super/hypermarkets fish products are sold via fresh fish counters and thus compete more directly with other products. Hence this change is expected to have lead to more elastic demand for fish products as more substitutes are available to the customers (Bjørndal *et al.* 1992).

Due to the huge increase in produced quantity (see Table 4 and Figure 3) in this industry, the prices for all three salmon products show a stable decreasing path. The developments in real prices are shown in Figure 10.

Figure 10

Monthly development of real prices of fresh, frozen and smoked salmon in the EU from 1981 to 1992 (Deflator: CPI index for the EU).



Although prices have been falling, the decline in prices is not as fast and distinct as the strong positive increase in quantity suggests. This is ascribed to positive shifts in the demand curve due to various factors, i.e. increase in income, increased concern about nutrition, extensive promoting by the producer associations and penetration of new market segments.

The decline in prices in the last part of the period initiated the crisis in the European salmon producing industry.

In their study of the market structure in the international salmon market, DeVoretz and Salvanes (1993) estimate demand models for the US and the EU, and compare own price elasticities to test for price discrimination. Since they use Norwegian export data their econometric results may also be interpreted as a Norwegian *residual demand* curve, which is thus downward sloping, (i.e., the own-price elasticity was found to be -2.14).[28] This suggests a non-competitive market structure (Baker & Bresnahan, 1988). However, they do not model the supply relation—the equilibrium condition that marginal cost equals perceived marginal revenue explicitly. They use an instrumental variable technique by which cost observations are only included as supply shifters. Hence, one should be careful when drawing conclusions about the form of the residual demand curve.

To summarise, the salmon market is price-elastic, and producers face a downward sloping demand curve, indicating a potential for producers to extract monopoly/oligopoly rent in the EU salmon market. On the other hand, the existence of substitutes reduces this possibility, and limits the participants' ability to engage in strategic price discrimination.

1.4. Organisational Structure

Several studies have argued that it is reasonable to treat Scotland and Norway as *units* (DeVoretz & Salvanes, 1988; DeVoretz & Salvanes, 1993; Herrmann & Lin, 1988). In Scotland this is mainly due to the industry structure, which is dominated by multinationals rather than small-scale farms, as in Norway. In 1986 the three biggest Scottish firms accounted for 50% of total Scottish salmon production.[29] An additional argument for such treatment is the Scottish producers' voluntary formation of their own production associations; Scottish Salmon Growers' Association Limited (SSGA), Scottish Salmon Farmers' Marketing Board (SSB), and Shetland Salmon Farmers' Association (SSFA). The most important, SSGA, was founded in 1982, and its

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[28]By residual demand curve, one thinks of the relationship between one firm's price and quantity, taking into account the supply response of all other firms. The residual demand curve of a firm in a perfectly competitive industry is flat, that of a monopolist is the same as the industry demand curve, and that of a firm in a product differenciated industry lies between these extremes (Baker & Bresnahan, 1988).

[29]The three producers are; Marine Harvest, a subsidiary of Unilever, McConnel Salmon, a subsidiary of the trading group Booker McConnel, and Golden Sea Produce, a subsidiary of the Norwegian Norsk Hydro group. In 1988 Marine Harvest was the largest salmon producer in the world (Bjørndal, 1990).

aim is to maximise its members' profits by collecting and internally distributing market information, maintaining quality standards, etc. In 1992 this association had 61 members, representing 80% of Scottish salmon production.

In Norway the argument for unified treatment is mainly based on the organisational structure, where the farm-gate sales of salmon were closely regulated until 1991. The Fish Farmers' Sales Organisation was authorised by the government to administer farm-gate sales, promote Norwegian salmon world-wide, maintain quality standards and collect market information. A government license was required for export until July 1991.

The Norwegian Fish Farmers' Sales Organisation (FFSO) was founded on March 31, 1978. It applied for the exclusive right to first-hand (farm-gate) sales of salmon and was granted this on July 28, 1978. The exclusive right was stipulated in the Norwegian law of December 14, 1951; '*Lov om råfisk*', which regulates all Norwegian first-hand sales of fish. The law is an enabling act that prohibits all first-hand sales to any but the governmentally appointed buyers (§2). Furthermore, the law delegates the authority to FFSO to set minimum prices and authorise buyers/exporters (§4) and to collect a producer fee to support its operations (§7a). The regulation of first-hand sales was in force from 16 October 1978 until the failure of FFSO 13 November 1991.

The minimum prices were set by FFSO after first consulting with the farmers and the exporters. The main goal of setting minimum prices was to maintain a higher price than what would have been possible in a perfectly competitive market (NOU 1992:36, p. 64). In this sense, FFSO functioned as a Norwegian price cartel. Hence, the argument for treating Norway as one *unit* could be rationalised on the basis of this regulation. Even if the exporters were not co-ordinated, they had to buy salmon at the price determined by FFSO (or a higher one). Given a downward sloping demand curve, FFSO could find the price that maximised net profit, and by choosing a first-hand (farm-gate) price that left a certain mark-up to the exporters, the cartel could set prices also internationally (Salvanes & Tveterås, 1992).

One problem with this line of arguments is that as long as FFSO had no possibility to effectively control the quantity, i.e., production volume and possible entry, the argument for the existence of an efficient cartel is weakened. Further, data on trade patterns indicate that neither producers nor consumers have preferences regarding trade partners, and exporters buy fish from not one, but several farmers, which suggests less integration than what the regulation scheme indicate (Bjørndal & Schwindt, 1989). Finally, during the 'cartel' period, 1978 to 1991, salmon was traded also at prices above the minimum prices, indicating a non-binding constraint over several years.

FFSO also functioned as a guarantor for payments. The farmers sold their salmon to the authorised buyers and were paid directly from FFSO. FFSO collected the money from the buyers. To monitor the transactions FFSO got the contracts, stating destination, foreign buyers, final use, packing etc., from the buyer. FFSO also had legal access to the buyers' accounts and information from customs authorities. The producer fee used for financing the operations of FFSO was a fixed share of sales.

FFSO's policy was to keep the number of buyers as low as possible, in order to ensure stable operating conditions and a minimum size. Another reason put forward for authorising buyers was to prevent *speculation in the market* (NOU 1992:36 p. 191). During the period from 1978 to 1991 there were on average 73 buyers . The number was relatively stable, varying between 65 and 80 during this period. Thus, the average buyer's quantity increased considerably during the period. In 1978 the average quantity was 68 tonnes; in 1991 it had increased to 2166 tonnes. (NOU 1992:36, p. 62). The average numbers underestimate the actual concentration in the industry, since the largest buyers have a relatively large share of the market. The 15 largest exporters and their exports of fresh and frozen salmon in the period from 1989 to 1990 are shown in Table 10. The cumulated percentages' shares are relatively high, indicating a concentrated market. The 10 largest buyers controlled nearly 60% of the Norwegian salmon supply, and the turnover of buyers was relatively low. Most of the buyers stayed in business during the whole period. Of the 72 authorised buyers in 1979, as many as 48 were still active in 1987. Of the 20 largest buyers in 1987, 14 were also active in 1979. Hence, the authorisation system, the concentration and the relatively high stability suggest some possibilities for co-ordination among the exporters.

FFSO was responsible for promoting Norwegian salmon abroad. Its main policy was to carry out generic marketing, i.e., advertising 'Norwegian salmon' as a quality concept rather then

Table 10

The 15 largest exporters and their exports of fresh and frozen salmon from 1989 to 1990.

Exporter No.	Export in tonnes	The percentage's share of total export	Cumulated percentage's share of total export
1.	32.402	15.4	15.4
2.	18.220	8.7	24.1
3.	15.938	7.6	31.7
4.	9.471	4.5	36.2
5.	9.044	4.3	40.5
6.	8.188	3.9	44.4
7.	8.106	3.9	48.3
8.	7.871	3.7	52.0
9.	7.201	3.4	55.4
10.	7.038	3.3	58.7
11.	4.578	2.2	60.9
12.	4.363	2.1	63.0
13.	4.131	2.0	65.0
14.	4.057	1.9	66.9
15.	3.899	1.9	68.8

Source: NOU (1992:36)

promoting the different exporters' products. The organisation also ran Norwegian marketing offices in Frankfurt, Madrid and Paris. Closely related to these marketing activities abroad, the FFSO also worked to maintain high quality standards for salmon. Salmon was divided into three quality groups, *superior*, *ordinary* and *production*. Only the two highest quality groups, *superior* and *ordinary* , were exported. During the 1985 to 1990 period, 76.5% of the salmon was of *superior* quality on average, 19% was *ordinary* and 4.5% was of *production* quality.[30] FFSO arranged quality seminars, prepared information material for the industry, and supported research on salmon.

With the industrial and organisational structure described above, and a very dominant position in terms of supplies, it seems that Norway and Scotland may have had some possibility to act as co-ordinated *units* in the EU market for salmon. In favour of such a view is the EU commission decision of July 1992 (No. 92/444) in which the two associations, FFSO and SSB,

[30]The average quality declined steadily during this period. In 1985, 90% of the salmon was *superior*, in 1990 the figure had fallen to 63%. This was due to two factors. The increase in production volume for the average firm made it technologically more difficult to achieve as high quality as earlier, and the Norwegian quality was higher than what the export markets actually demanded. Hence, the quality premium given by FFSO was reduced during this period to provide incentives to reduce the average quality.

were condemned for price collusion in the EU.[31] One of the main arguments in the Commission's decision was the organisational structure of these associations, and their ability to co-ordinate and influence salmon prices in the EU. Hence, important participants in the market held a co-ordinated unit view.

Another rationale for treating Norway as a unit is the fact that by starting the freezing program, FFSO actually had to believe that they *could* influence prices in the EU. On January 4, 1990 the FFSO board made the formal decision of starting the freezing program. Their aim was to *'maintain the balance of supply and demand'* in the salmon market. The original plan was to freeze 45 000 tonnes of salmon in 1990, representing 30% of the estimated Norwegian salmon production this year. The remaining 110 000 tonnes were to be sold in the market. The estimates were based on the amount of smolts released in 1988. They hoped to end the program by 1991, since the amount of smolts released in 1989 was lower, and 1990 was thought to be a peak year.

The program was financed by a loan of 1 billion NOK and a fee of 5 NOK per kilo fresh salmon sold in the market. During the program period the producer had two possibilities, either to sell to the freezing program at the given minimum price, or to sell in the fresh market at the market price deducted the 5 NOK. Hence, it was only profitable to sell in the fresh market if the market price were 5 NOK higher than the minimum price set by FFSO (for frozen salmon).

Due to even lower sales than planned, FFSO had to freeze as much as 54 000 tonnes of salmon in 1990. This was ascribed to several factors, e.g. a particular large wild Pacific salmon harvest, the US' retaliatory tariff, development in exchange rates and irregular sales of salmon outside FFSO (to save the per kilo fee).

By the end of 1990, FFSO had sold 55% of the 54 000 tonnes. However, they had been unsuccessful in stabilising the price level in the salmon market, and the market prices were still regarded as 'too low'. Facing this, the remaining stocked frozen salmon and a 1991 production higher than anticipated, FFSO continued the program in 1991. An increasing problem now evolved: freezing of salmon at minimum price combined with low market prices generated an artificial national market for frozen salmon. It became more profitable to sell in this national

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[31] *Trade policy Review*, European Communities, volume I, 1993, GATT, pp. 125-126.

market than in the international market, and several producers actually directed salmon only for the freezing program. Due to the large quantity involved, and the low market price of frozen salmon, the cost of the program got substantially higher cost than what the FFSO could sustain with the fee of 5 NOK per kilo. Even with an additional loan of 600 million NOK in June 1991, the lack of liquidity made FFSO end the freezing program in July, 1991.[32] As a result of the failure of the freezing prorgram, FFSO went bankruptcy in November, 1991.

After November 1991, the situation has changed. The industry structure has changed and a more horizontally and vertically integrated industry has emerged. There is however, no alternative organisation to replace FFSO, which implies that there probably is a more competitive industry today. However, as a whole, the structure of this industry in the period before November, 1991 provides support for treating Norway as one *unit* during the period prior to the FFSO failure.

1.5. The Market Structure

Earlier studies on market structure have taken different views. Bjørndal and Schwindt (1989) conclude that there is a competitive market. They argue against the co-ordinated unit view, on the basis of several observations. First, Norway's market share of the world production of salmon (wild salmon included) is relatively low (see Table 1). Second, neither producers nor consumers have preferences regarding trade partners, and exporters buy fish not from one, but several farmers. Finally, there is a large number of independent exporters and farmers.

Due to Norway's dominant position in the farming industry, also models in which Norway is assumed to have monopoly power have been suggested (Singh, 1988). The problem with this view is that as long as there exist substitutes to Norwegian salmon, a monopoly model is not appropriate. Others have suggested that models with segmented markets should be applied (DeVoretz & Salvanes, 1988; Herrmann & Lin, 1988a; 1988b). DeVoretz & Salvanes (1988) model France as a primary market with a higher mark-up than the rest of the world. They argue

[32]The freezing program is thoroughly analysed in NOU 1992:36.

that Norwegian salmon is exported to the primary market, France, until total revenue is maximised (i.e., the own-price elasticity is close to *one* in absolute value) and then exported to less important secondary markets. Both of Herrmann and Lin's studies assume that the EU and the US are two different segments. By basically estimating demand models and interpreting the results, they find support for a non-competitive market structure. Based on these studies, DeVoretz and Salvanes (1993) modelled the market structure problem more explicitly and tested models with varying degrees of market power including third-degree price discrimination. They found that Norwegian exporters only had limited ability to engage in regional price discrimination. More specifically, they did not find significant differences in demand elasticities between the markets in the US and Europe, and concluded that the observed price differences (in CIF prices) were explained by differences in transportation costs. However, they found that discrimination may have taken place after the third quarter in 1987. They also found that seasonal price discrimination could have taken place in the periods when fresh wild caught salmon was unavailable.

A problem with the segmented market view is that as long as one has no clear cut definition of what the segments are, the models must be based on more or less *ad hoc* definitions of the market segments, which could undermine the empirical tests undertaken. For this reason, in addition to an analysis of the market structure, an analysis of the market boundaries should be carried out in order to define the appropriate segments.

After summarising the results from these studies and analysing the market characteristics, Bjørndal & Salvanes (1992) conclude that the market is competitive in the long run, but that Norway may have some possibility to engage in intertemporal price discrimination. Further, since possible new participants face 2 to 3 year growth-out periods after entry, they argue that there may be some room for exercising market power in the short run. A general argument also against these is, of course, the existence of substitutes (see section 3).

As discussed in section 4, there was a quite strong belief in the market that Norway had some market power and ability to set prices. In July, 1992 the EU Commission found the Scottish and Norwegian salmon producers guilty of collusion to set minimum prices in the EU. They were found guilty of infringing the EU-treaty article 85(1), Section IV.4(i) on price agreements. Their agreement was found to '*have as its object and effect the restrictions of distortion of competition in the common market; it was likely to have an appreciable effect in particular on trade between the continental and the salmon producing EC member states'*.[33]

In the middle of 1989 the salmon industry was in crisis. Despite a significant increase in demand for farmed salmon, prices had been steadily declining. As a result of this, in late 1989 FFSO was deliberating over whether to start its freezing program for salmon which producers were unable to sell on the market at the minimum price level. They conferred with the Scottish organisations for advice and on December 20, FFSO organised a telephone conference with the Scottish producers in order to get support for their new policy (freezing program and new minimum prices,). As a result SSB, SSGA and SSFA sent circulars to their members to urge them to bring their prices into line with the new Norwegian minimum prices.[34] The agreement involved SSB's forwarding internal price information collected by SSGA to FFSO so that they could check for undisciplined Scottish price behaviour, and if such behaviour was found, to start mutual investigations. The agreement ended on October 2, 1991 when SSB wrote to its members withdrawing the circulars. At this time SSB also said to its members, as well as its Norwegian counterpart, that '*it was not its function to influence any price decisions...*'. In November 1991, the failure of FFSO brought its minimum price system and freezing program to an end. The Commission's verdict was based on a belief that the Norwegian minimum prices set by FFSO "*...set the benchmark for farmed salmon prices (in Europe).*"[35]

Even though this was a legal decision, and not necessarily the 'truth' about this market, it shows that central participants in this market were believed to act strategically, and that Norway was regarded as one dominant unit able to influence price. However, even though there is no consensus in the literature, reecent studies conclude that there was a competitive market, at least in the long run. In support of this view is the relative high number of participants in this market, and the existence of substitutes. In conclusion, the answer to the question of market structure is

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[33]*Trade policy Review*, European Communities, volume I, 1993, GATT, pp. 126.

[34]The Norwegian producers restored minimum prices as from January, 2 1990. SSB noted that this had '*raised general market price levels throughout the world...*'.

[35]The EU Commission, legal document 30, July 1992 No. L, (92/444/EØF), pp. 246/37-246/45, *Trade policy Review*, European Communities, volume I, 1993, GATT, pp. 125-126 and Press Report from EU August 3, 1992 (Ref.:IP/92/673).

ambiguous. However, the existence of a downward sloping demand curve and dominant suppliers, the industrial and the organisational structure on the supply side, serve as arguments for Norway and Scotland's having some market power in the short run, particularly prior to the failure of FFSO in 1991. Further, due to the intertemporal restrictions in the North American supply of wild salmon, models allowing also for intertemporal price discrimination may be appropriate in this market.

1.6. A Research Agenda

The supply side of salmon in the EU is dominated by a few large countries, Norway, Scotland, the US and Canada. In particular, the market for fresh salmon is concentrated, and Norway and Scotland account for 80 to 90% of the market.

Central participants in this market have regarded Norway and Scotland as market leaders with an ability to influence prices and exercise market power in the EU market. The producer associations in Norway and Scotland were found guilty for constituting an agreement on price co-ordination in EU by the EU Commission in 1992.

The literature on market structure is ambiguous, though the conclusion is that there seems to be a competitive market in the long run. However, the market characteristics and the literature provide arguments which indicate that Norway and Scotland may have had some oligopolistic market power in the short run. Further, due to the intertemporal restrictions in the North American supply, models allowing for intertemporal price discrimination may be appropriate in the EU salmon market.

With the exception of DeVoretz and Salvanes (1993), no one has tried to model and test for market structure explicitly using new empirical industrial organisation models in this industry. This leaves empirical issues about market structure open for research, and defines the point of departure for this dissertation.

The survey in section 5, showed that the most recent empirical studies are based on a segmented market view. This motivates the main topic of the next two chapters, *market delineation*. Recently, there has been a rapid growth in empirical studies focusing on firm and industry conduct, the existence of market power and various forms of imperfect competition. Since these analyses typically make an extensive use of market characteristics, such as market shares, market structure, the relevant market needs to be defined. This also applies to the salmon market. Norway supplied 52% of the world production of farmed salmon in 1990. When considering farmed and wild production, Norway's market share was only about 15%. However, in important sub-markets, Norway's market share is as high as 80% (wild salmon included). Hence, it is obvious that the market definition, i.e., *one* world market or *several* sub-markets, is crucial for the discussion of market structure and Norway's role.

There is a growing literature on market delineation using econometric time series techniques to test for price interdependencies. All of these studies are based on Stigler's (1969) definition of a market, where arbitrage will ensure that the law of one price applies. In chapters 2 and 3, multivariate cointegration tests are proposed as a market delineation tool. When cointegration is verified, variables exhibit a stable long-run relationship, which implies that a spatial price parity equilibrium condition exists. The prices may drift apart from one another in the short-run due to random shocks, sticky prices, contracts etc., but in the long-run, economic equilibrium processes force the variables back to their long-run equilibrium paths.

In chapter 2 the EU market for salmon is analysed. In the product space, we focus on the three main products, fresh, frozen and smoked salmon. As we saw in section 3 in this chapter, empirical studies have concluded with varying degrees of substitutability between fresh and frozen salmon, and both frozen and fresh salmon are used as inputs in the smoked salmon industry. On the other hand, the consumers may perceive differences in quality between fresh and frozen salmon, and smoked salmon is not consumed in the same way as the other two products. Hence, the picture is ambiguous and there are no clear-cut arguments for *one* versus *two* or *three* markets.

Tests for spatial price discrimination will also be undertaken. We will perform cointegration tests both for frozen and fresh salmon. We focus on six countries/areas; France, Belgium/Luxembourg, Holland, Germany, UK and Denmark, representing between 86 and 97% of the EU market for fresh and frozen salmon during the period 1981 to 1992.

We have shown that seasonality, both in supply and demand, is important in the salmon industry. In the market delineation analysis in chapter 2, the importance of seasonality is also analysed. In particular, the problem of stochastic seasonality when employing cointegration tests on seasonal data will be addressed. When testing for long-run relationship one is basically interested in the long-run processes. However, stochastic seasonality may act as noise in the variables, making the cointegration methodology less able to reveal a possible long-run relationship. Hence, we will exploit Beaulieu & Miron's (1993) test for seasonal integration feature of distinguishing between different seasonal unit roots. We test for seasonal integration, and based on the results, we calculate appropriate filters to extract seasonal unit roots, leaving only the long-run zero frequency processes. Finally, the new filtered series will be used as inputs in the cointegration tests. Empirically this approach to seasonality will provide clearer and more distinct cointegration results than when applying the cointegration tests only using the unfiltered series.

In chapter 3, we go a step further, investigating the intertemporal dimension of the salmon market. Using the cointegration technology we test for intertemporal price discrimination in the European salmon market. Due to the harvest seasons, fresh North American salmon is available only during certain periods. The degree of competition will thus be lower in some periods, and higher in others. In chapter 3, market delineation methods will be used to test for intertemporal price discrimination and the significance of intertemporal changes in competition. By dividing the data set into two parts, a low-competition period data set and a high-competition period data set, undertaking cointegration tests on both data sets and comparing the results from the two regimes, we may test for the significance of intertemporal changes in competition.

After having established the market boundaries, and the importance of intertemporal changes in the level of competition, we model the market structure more explicitly in chapter 4. We have already established the dynamic nature of the salmon market. Hence, an adequate modelling of this market must allow for dynamic behaviour. In chapter 4 we propose a dynamic extension of the oligopoly model of Bresnahan (1988) and Lau (1988). The model is reformulated in an error correction framework. The framework solves both statistical problems generated by short term dynamics in the data, and incorporates important dynamic factors as habit formation from the demand side and adjustment costs for the producer. By modelling a dynamic demand function and a dynamic supply relation the model provides a summary statistic that can be interpreted as the percentage of monopoly marginal revenue perceived in a market. The model provides both a short run and a long run measure of this statistic. The model is applied to the French market for fresh salmon, where Norway's role is analysed.

The three analyses, together with this chapter, are meant to give a better understanding of the market structure in the EU market for salmon. In particular, questions about market boundaries, intertemporal changes in competition and market power are addressed. The problem is approached by providing new data, and analysing these from different points of view. Market structure has previously not been addressed as extensively as in this dissertation. The three following chapters consist of three independent studies, and may be read separately. However, all three focus on the same market from different perspectives and are therefore complimentary regarding the main focus of this dissertation, an empirical analysis of market structure in the EU market for salmon.

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Appendix 1A: Data Description and Variable Definition

The analysis uses monthly import data from the EU trade statistics, EUROSTAT, from 1981 to 1992 (n=144). The data is extracted from EUROSTAT's COMEXT database Chapter 3 "*Fish and Crustaceans, molluscs and other aquatic invertebrates*". Prior to 1988, fresh salmon was registered as one aggregated product, No. 030103 (EUROSTAT's HS-nomenclature), 'Fresh or chilled Pacific salmon "Oncorhyncus SSP" and Atlantic salmon "Salmo Salar" and Danube salmon "Hucho hucho"'. In 1988 it was dissaggregated into No. 03021200, fresh or chilled salmon and No. 03041013, fresh or chilled fillets of salmon. Hence, to ensure compatibility from 1988 to 1992 these two groups are aggregated. A parallel harmonisation is done for frozen salmon. Prior to 1988 No. 030104, 'frozen Pacific salmon "Oncorhyncus SSP", Atlantic salmon "Salmo Salar" and Danube salmon "Hucho hucho" is used. From 1988 to 1992 No. 03031000, frozen Pacific salmon, No 03032200, frozen Atlantic salmon and No. 03042013 frozen fillets of all salmon are aggregated. Smoked salmon is one aggregated group in EUROSTAT's database, Pacific salmon "Oncorhyncus SSP", Atlantic salmon "Salmo Salar" and Danube salmon "Hucho hucho", smoked, including fillets. Prior to 1988 the nomenclature code for smoked salmon was 030233, and from 1988 to 1992 the code was 03054100. The data was provided by EUROSTAT and was prepared for the present purpose at The Norwegian College of Fishery Science, University of Tromsø, Tromsø, Norway. All values are in ECU, and prices FOB. The prices used are unit prices, i.e. value divided by quantity. All nominal figures were deflated using the corresponding consumer indices using 1985 as the base year. The individual country indices were from IMF's international financial statistics, the EU consumer index was from the OECD statistics.

—Part II—

Market Delineation

"The market, like the weather, is simply there, whether we only talk about it or do something"
(Adelman, 1961, p.237)

—Chapter 2—

Multivariate Cointegration, Stochastic Seasonality and Market Delineation: An Application to the EU market(s) for Salmon

2.1. Introduction

There is a growing literature on market delineation using econometric time series techniques to test for price interdependencies.[1] All these studies are based on Stigler's (1969) definition of a market, where arbitrage will make sure that the law of one price applies.[2] The most recent studies on market delineation employ bivariate cointegration tests as a market delineation methodology (Ardeni, 1989; Goodwin & Schroeder, 1991). In this chapter we propose the use of multivariate cointegration tests as a market delineation tool. We also address the problem of stochastic seasonality when employing cointegration tests on seasonal data. This is done by removing seasonal cycles prior to the cointegration tests. Both geographic market boundaries and product space boundaries are tested for.

When cointegration is verified, variables exhibit a stable long-run relationship, which implies that a spatial price parity equilibrium condition exists. The prices may drift apart from one another in the short-run due to random shocks, sticky prices, contracts etc., but in the long-run, economic equilibrium processes force the variables back to their long-run equilibrium paths (Engle & Granger, 1991). Variables could cointegrate even though one or more of them do not significantly contribute to the long-run relationship (Hamilton, 1994). For instance, price series which in general have independent processes could be weakly cointegrated if they are exposed to substantial common cost, or demand shocks, rather than the economic activities relevant to market delineation such as substitution and arbitrage. Thus, in addition to the multivariate test for cointegration, we therefore also undertake exclusion tests on the long-run parameters to ensure the robustness of the cointegration relationships.

When testing for long-run relationship one is basically interested in the long-run zero frequency processes. However, stochastic seasonality may act as noise in the variables, making the cointegration methodology less able to reveal a possible long-run relationship. Hence, we exploit Beaulieu & Miron's (1993) test for seasonal integration feature of distinguishing between different

[1]See for instance Horowitz, (1980), Stigler, (1985), Benson and Faminow (1990) and Schrank & Roy, (1991) for a review of the time series approaches to market delineation.

[2]Stigler (1969, p. 85) defined an economic market as: "*The area within which the price of a commodity tends to uniformity, allowance being made for transportation costs*".

seasonal unit roots. We test for seasonal integration, and based on the results we calculate appropriate filters to extract seasonal unit roots, leaving only the long-run zero frequency processes. Finally, the new filtered series are used as inputs in the cointegration tests. Empirically we find this approach to seasonality providing clearer and more distinct cointegration results, than what we get when applying the cointegration tests only using the unfiltered series.

Recently one has seen a rapid growth of empirical studies focusing on firm and industry conduct, the existence of market power and various forms of imperfect markets.[3] Since these analyses typically make an extensive use of market characteristics, (e.g. market shares, market structure, etc.), it is required to define the relevant market. Several studies have focused on the market structure in the international salmon market (DeVoretz & Salvanes, 1993; Herrmann & Lin, 1988a; 1988b; Bjørndal & Schwindt, 1989). There is no consensus on how to define the market in these studies. Norway supplied 52% of the world production of farmed salmon in 1990. When accounting for total harvest of wild salmon, Norway's market share was only about 15%. However, in important sub-markets Norway's market shares are as high as 80% of total supply (wild salmon included). Hence, it is obvious that the market definition, i.e., *one* world market or *several* sub-markets, is crucial for the discussion of market structure and Norway's role.

The European Union (EU) market for salmon is analysed. In the product space, we focus on the three main products, fresh, frozen and smoked salmon. Empirical studies have concluded with varying degrees of substitutability between fresh and frozen salmon, and both frozen and fresh salmon are used as input in the salmon smoking industry (DeVoretz & Salvanes, 1993, Bjørndal, *et al*, 1992). On the other hand, the consumers may perceive differences in quality between fresh and frozen salmon, and smoked salmon is not consumed in the same way as the other two products. Hence, the picture is ambiguous and there are no clear-cut arguments for *one* versus *two* or *three* markets. We find evidence for fresh, frozen and smoked salmon to be in the same market, i.e., the price series cointegrate and all the three products contribute significantly to the long-run relationship. Tests for spatial price discrimination are also undertaken. These are more ambiguous, suggesting two different geographic markets for frozen salmon in the EU: one market in France,

[3]For a review of this literature see Bresnahan, (1989) and Slade, (1994).

and the rest of the EU as an aggregated group. The market for fresh salmon is found to be more integrated, i.e., one EU market for fresh salmon.

The chapter is organised as follows. In the next section a short review of the time series approach to market delineation is presented. Section 3 presents the methodology—seasonality and multivariate cointegration tests. Section 4 describes the analysed market. In section 5, the empirical results from the Beaulieu & Miron tests are discussed, and in section 6 we present the cointegration results. Concluding comments are presented in section 7.

2.2. Market delineation — A Time Series Approach

The literature on market delineation relies heavily on the interdependence of prices across markets and the arbitrage principle (Horowitz, 1981; Stigler & Sherwin, 1985; Slade, 1986; Higginson, *et al*, 1988; Benson & Faminow, 1990; Schrank & Roy, 1991; Weiner, 1991).[4] The first studies were basically investigating the correlation of prices between markets (Horowitz, 1981; Stigler & Sherwin, 1985). However, these models had several shortcomings.[5] Horowitz's adaptive lag-price model was an attempt to find a more sophisticated methodology, but has been criticised for assuming stable price differences between markets and assuming an unnecessary restrictive adjustment mechanism after temporary price shocks (Slade, 1986; Giffin & Kushner, 1982). The next generation of models was based on Granger (1969) and Sim's (1972) work on causality, where one checks whether price determination in one region is exogenous to price formation in another (Slade, 1986; Uri & Rifkin, 1985; Higginson, *et al.*, 1988; Benson & Faminow, 1990). Benson & Faminow and Uri & Rifkin used autoregressive models to test for instantaneous Granger

[4]Parallel to this view an antitrust literature on market delineation using the market definition in the US. Department of Justice's merger guidelines has emerged (Werden, 1992; Werden & Froeb, 1991). As opposed to using the criterion of price interdependencies one here defines a relevant antitrust market as the smallest relevant group of products and geographic areas (with the parties to merger as the focus on the group) that could, if cartelized, profitably exercise market power. Hence, the market defined in these studies will not necessarily overlap with the market defined by interdependencies of prices (Scheffman & Spiller, 1987).

[5] Common movements due to common cost and demand shocks could lead to high correlation coefficients and thus support one market erroneously. Further, correlation analysis cannot account for multi-period lagged responses to price shocks, i.e. if the response is delayed contemporaneous correlation may be small even when two series are perfectly correlated in the long run (Slade, 1986).

causality. Slade and Higginson *et al.* used multivariate vector autoregressive models (VAR) utilising the exogeneity concept when testing for causality. The VAR model is superior in capturing feedback processes in the price series and both models account for the problem of autocorrelation. However, these models demand stationary price series to capture the long-run properties of the variables appropriately. Most time series are found to be non-stationary in their levels. Hence, stationarity is commonly achieved by first differencing the price series. Differencing is not a solution *per se* to the problem of nonstationarity and stability of the parameters of the model. Differencing eliminates all information about the long-run relationship, and restricts the model's ability to account for short-term dynamics (Hendry, 1986; Plosser & Schwert, 1978). Hence, Ardeni (1989) and Goodwin and Schroeder (1991) introduce cointegration tests to test for market boundaries. The idea of cointegration is that even if two or more variables in themselves are not stationary in the levels, linear combinations (so-called cointegration vectors) which are stationary may exist (Engle & Granger, 1987). When cointegration is verified, variables exhibit stable long-run relationship, which in this context implies that a spatial price parity equilibrium condition exists. The variables may drift apart from one another in the short-run due to random shocks, sticky prices, contracts etc., but in the long-run, economic equilibrium processes force the variables back to their long-run equilibrium paths (Engle & Granger, 1991). Hence, cointegration tests are superior when the investigated relationships are believed to be of long-run nature.

Ardeni and Goodwin & Schroeder, utilise the Engle and Granger approach which is restricted to pairwise comparisons of prices. Usually there are more than two areas or products and there could be close links between them. Bivariate methods ignore possible linkages which may operate through another market within the system. There might also be a number of multiple long-run equilibrium relations, but these cannot be fully captured by bivariate methods. Johansen (1988; 1991) and Johansen & Juselius (1990) have developed a multivariate method that accounts for this problem by providing a matrix with all possible distinct cointegrating vectors based on all the variables investigated.[6] Cointegration vectors could be thought of as representing constraints that

[6] It is also possible to use the Engle & Granger method to find multivariate two step estimators for the cointegration vectors. However, if more than one cointegration vector is found, the method provides no information on which to choose, *and* whether these in fact represent several distinct equilibrium vectors or are a result of sampling

an economic system imposes on the movements of the variables in the system in the long-run. Hence, the more cointegration vectors there are, the more stable the system is (Dickey*et al*, 1991). Johansen and Juselius provide test statistics allowing us to determine the number of significant cointegration vectors. Variables could cointegrate even though one or more of them do not significantly contribute to the long-run relationship, i.e., the other variables in the system are the 'main contributors' to the significant cointegrating relation. For instance, price series which in general have independent processes could be weakly cointegrated if they are exposed to substantial common cost, or demand shocks, rather than the economic activities relevant to market delineation such as substitution and arbitrage. The Johansen and Juselius methodology allows you to test this by implementing null restrictions on the long-run parameters—exclusion tests (Hamilton, 1994, pp. 648-50).

We will employ the multivariate cointegration methodology for delineating markets. If arbitrage takes place, prices will move together in the long-run. Hence, when testing for cointegration one will expect these series to cointegrate. However, to conclude that products or areas belong to the same market we also undertake exclusion tests of the long-run parameters, requiring the parameters to be significantly different from zero.

2.3. Methodology: Integration and Cointegration

Consider two series of economic variables, x_t and y_t. Each series by itself is nonstationary and requires to be differenced once to produce a stationary series. However, a linear combination of the two series;

(1) $$y_t - \psi x_t = \varepsilon_t$$

may produce a residual series ε_t which is stationary. In this case, the series x_t and y_t are said to

variance. Secondly, as opposed to Johansen and Juselius' approach, the test statistics in the Engle & Granger method cannot be compared with critical values from well-defined limiting known distributions, as the distributions is a function of the whole data-generation process (which is of course unknown).

be cointegrated. Or more precisely, the series are said to be *cointegrated of order (1,1)* with the vector $[1, -\psi]$ called the *cointegration vector.* A straightforward generalisation for the case of *n* variables is the following. If x_t denotes an $n \times 1$ vector of series $x_{1t}, x_{2t}, \ldots, x_{nt}$ and each of them is *I(d)* and there exists an $n \times 1$ vector β such that $\mathbf{x}_t' \cdot \beta \sim I(d-b)$ (where $d \geq b \geq 0$), then $\mathbf{x}_t' \cdot \beta$ is cointegrated of order d,b (Engle & Granger, 1987).

Before testing for cointegration, one has to verify the variables' integration order. The most common test for integration is the test for a zero frequency unit root developed by Dickey and Fuller (1979; 1981).[7] The development in a series x_t is assumed to be described by an autoregressive process AR(1);

(2) $$\mathbf{x}_t = \rho \cdot x_{t-1} + \varepsilon_t,$$

where $\varepsilon_t \sim iid(0, \sigma)$. When $\rho = 1$, this process is nonstationary, i.e. it has a unit root. However, if $|\rho| < 1$, the series is stationary in the levels. Thus, the null hypothesis of a unit root tested for in the Dickey Fuller test is $\rho = 1$.

However, this test is not necessarily appropriate when dealing with seasonal data. Price series could move along different cycles within one year, e.g. caused by seasonal variation in demand, biological or economical supply-side cycles. The seasonal variation would usually be stationary, but might also be stochastic. In the latter case the seasonal pattern is changing and is not constant—the series is seasonally integrated.[8] *By applying ordinary Dickey Fuller tests for a long-run zero frequency unit root at seasonal data, one automatically neglects the problem of stochastic seasonality, usually referred to as existence of seasonal unit roots.* Stochastic seasonality will act as noise in the cointegration tests, and reduce the tests' ability to reveal the long-run cointegration relations. In the salmon industry seasonal variation is important. Due to biological supply side conditions (i.e., stochastic variation in Pacific salmon stocks, algae outbreaks, diseases

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[7]Zero frequency refers to the long run frequency with no cycles within the period.
[8]Hylleberg, *et al,* (1991), argue that in sectors such as agricultural production and especially in monthly data series (compared to quarterly series) the problem of changing seasonal patterns are important.

etc.) one may get changing seasonal patterns. Further, demand shifts in accordance to seasons, with demand tops due to Easter and Christmas celebration (Bjørndal, 1990; Bjørndal, Salvanes & Andreassen, 1992). Promotion of salmon as an all year product together with a considerable decrease in real prices, may have led to changes in the seasonal demand pattern. Hence, tests for seasonal integration are undertaken. Based on the results we calculate appropriate filters to extract seasonal roots, leaving only the long-run zero frequency processes in the series. Finally, we use the new filtered series as inputs in the multivariate cointegration tests. Two techniques are developed for testing for seasonal unit roots, both along the lines of the Dickey-Fuller test; the Dickey-Hasza-Fuller (1984) test, later modified by Osborne et. al. (1988), and the Hylleberg, Engle, Granger and Yoo (1990) (HEGY) procedure.[9] Both procedures also account for purely deterministic seasonal processes. However, only the HEGY approach allows one to distinguish processes which may be integrated at only some seasonal cycles. Franses (1990) and Beaulieu & Miron (1993) have extended the HEGY procedure for time series consisting of monthly observations. The Beaulieu & Miron (BM) approach is applied here.

2.3.1. A Test for Seasonal Integration

An integrated seasonal process can be written as ;

(3) $$x_t = x_{t-12} + \varepsilon_t,$$

where $\rho = 1$, see equation (2). Using a backward shift operator B, to be defined as $B^k x_t \equiv x_{t-k}$, (3) can be rewritten as;

(4) $$(1 - B^{12})x_t = \varepsilon_t.$$

[9]Recently Canova & Hansen (1992) extend the test of Kwiatkowski, *et al*, (1992) to the seasonal case (quarterly), and propose a test based on the residuals from a regression extracting possible deterministic seasonal processes. Comparing this to the HEGY test using Monte Carlo experiments conclude that in particular when restricted by relatively small samples, the HEGY test has the best performance(Hylleberg, 1993).

The polynomial $(1-B^{12})=0$ has 12 solutions lying on the unit circle, which give 11 seasonal unit roots in addition to the long run zero frequency unit root.[10] Factorizing $(1-B^{12})$ in its real parts gives;

(5) $$(1-B^{12})=(1-B)(1+B)(1+B^2)(1+B+B^2)(1-B+B^2)$$
$$(1+\sqrt{3}B+B^2)(1-\sqrt{3}B+B^2)$$

Except for the first two parentheses on the RHS where both roots are real (1,-1), the roots of the five following parentheses are complex conjugates. For instance, the third parenthesis $(1+B^2)$ has two complex roots which are conjugates; $\pm i$, and thus, can be written as $(1-iB)(1+iB)$. The calculation of the remaining 8 complex roots are shown in Appendix A. Except for the first parenthesis at the RHS in (5) which represents a root at the long run zero frequency, we thus have 11 possible seasonal roots. All of the seasonal roots correspond to different cycles per year with corresponding frequencies, e.g. the roots $\pm i$, correspond to 3 and 9 cycles, and frequencies $\pi/2$ and $-\pi/2$, respectively. To relate these roots to frequencies in an intuitive way, consider the deterministic process; $\alpha(B)x_t=0$. For $\alpha(B)=(1+B)$ (i.e. corresponding to a case where the root is -1) the process $(1+B)x_t=0$ could be rewritten as; $x_{t+1}=-x_t$, and so $x_{t+2}=x_t$; the process returns to its original value after 2 periods, thus, 6 cycles during a year. All roots, corresponding cycles and frequencies are presented in Table A1 in Appendix A.

Beaulieu & Miron now formulate an auxiliary regression equation. This is essentially based on a linearizing of the polynomial $(1-B^{12})$ around the long run zero unit root plus the (S-1) 11 seasonal unit roots;

(6) $$\varphi(B)^*(1-B^{12})x_t=\sum_{k=1}^{12}\pi_k y_{k,t-1}+m_0t+m_1+\sum_{k=2}^{12}m_kS_{kt}+\varepsilon_t,$$

[10]This is easiest seen if one factorizes $(1-B^{12})$ as $(1-B)(1+B+B^2+...+B^{11})$ where the first is the well known first difference operator, and the last term is a moving average seasonal filter containing 11 further roots of modulus unity.

where $y_{k,t-1}$, $k = 2,\dots,12$ are differenciated versions of the original series x_t, $m_0 t$ is a time trend, m_1 a constant term and m_k $k = 2,\dots 12$ are seasonal dummies. Each of these y series represents the original series' seasonal movements along the different cycles, or more precisely, each y series represents an x series movements along one specific seasonal cycle, filtered for all other integrated seasonal cycles and the long-run zero frequency process. The latter is represented by $y_{1,t-1}$, and has an analogous interpretation. Thus, the parameter π_1 will have the same interpretation as the ordinary Dickey-Fuller parameter, but here all possible seasonal unit roots are removed.[11] All the filters used to calculate the y series are presented in appendix A. The polynomial $\varphi(B)^*$ on the LHS is a general form of a stationary polynomial in the back shift operator, representing the roots outside the unit circle. It is chosen in an appropriate way to whiten the residuals and thus take care of the autocorrelation problem in the auxiliary regression.[12]

In order to test hypotheses about various unit roots we now estimate (6) by OLS and then compare the OLS test statistics with the calculated critical values in Beaulieu & Miron (1993) (BM). The unit root hypothesis is accepted if $\pi_k = 0$. [13] To show that no unit roots exist at any seasonal cycles one needs $\pi_k \neq 0$, for all $k = 2,\dots,12$. In addition, if $\pi_1 = 0$,such a series corresponds to an *I(1)* annual series with a long-run zero frequency.

We now exploit the BM procedure's feature of distinguishing between the different seasonal

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[11] To find the filter used to calculate $y_{1,t-1}$ one applies the polynomial on the RHS in (5), using the last 6 parentheses, simplify and factorize this polynomial;

$$y_{1,t} = (1+B)(1+B^2)(1+\sqrt{3}B+B^2)(1-\sqrt{3}B+B^2)(1+B+B^2)(1-B+B^2)x_t$$
$$= (1+B+B^2+B^3+B^4+B^5+B^6+B^7+B^8+B^9+B^{10}+B^{11})x_t$$

Hence, $y_{1,t}$ represents the long run movements in x_t where all 11 seasonal unit roots are removed. By lagging $y_{1,t}$ once one gets the first regressor in (6); $y_{1,t-1}$.

[12] The power of the HEGY test is negatively affected if too many degrees of freedom are used. Hence, k must be chosen with care. By utilising Monte Carlo simulations using the HEGY test for quarterly data, Hylleberg *et. al.* (1993) find that to many lags lead to an overestimate of the number of unit roots, and that to few lags lead to rejection of far to many unit roots.

[13]The null hypothesis is $H_0: \pi_k = 0$, while the stationary alternative is $H_1: \pi_k < 0$. The first two π_1 and π_2, are tested using an ordinary t-test, while $\pi_k, k = 3,\dots,12$, are usually tested by applying pairwise F-tests for $\pi_i \cap \pi_j = 0$, $i = \{3,5,7,9,11\}$ and $j = \{4,6,8,10,12\}$. This is due to a conditional relationship between π-even and π-pair, e.g. conditioned on $\pi_3 = 0$, one could test for $\pi_4 = 0$ using an ordinary t-test, otherwise one has to use an F-test for $\pi_3 \cap \pi_4 = 0$.

unit root. In a case where only some seasonal unit roots are present, the BM procedure allows us to calculate filters which transform the series by only removing these specific roots.[14] Stochastic seasonality will act as noise in the cointegration tests, and reduce the test's ability to reveal the long-run cointegration relations. Since we are basically interested in possible long-run equilibrium relationship we thus extract the seasonal roots, and leave only the long-run zero frequency unit root in the series. These new transformed series are then used as inputs in the Johansen procedure.

2.3.2. The Multivariate Cointegration Methodology

Johansen (1988) shows how to find the number of cointegration vectors in a given set of variables. The methodology is later expanded to also account for factors such as deterministic seasonality and time trends in Johansen and Juselius (1990) and Johansen (1991). Even though the methodology is quite complex, the intuition behind it is more straightforward. To find the possible stationary linear combinations, the cointegration vectors, one divides the data into two groups, the variables in levels, and their first differences. Under the assumption of $I(1)$ processes, the differenced data are stationary. Using the technique of canonical correlation from the theory of multivariate analysis, the linear combinations of the data in levels that are highly correlated with the differences are found. If the correlation is sufficiently high, it follows that these linear combinations are stationary, and so are the cointegration vectors.

More formally, the vector of N variables $\mathbf{x}_t$, is assumed to be generated by an unrestricted vector autoregression (VAR) in the levels of the variables;

$$\mathbf{x}_t = \Pi_1 \mathbf{x}_{t-1} + \ldots + \Pi_k \mathbf{x}_{t-k} + \Phi D_t + \mu + e_t \tag{7}$$

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[14]For instance, take a series x_t characterised by 5 seasonal unit roots, in addition to the usual long run zero frequency unit root, i.e. $\pi_k = 0$ for $k = \{1,2,5,6,7,8\}$. To obtain an *I(1)* series containing only the long run zero frequency unit root one transforms this series with the following filter; $(1+B)(1+B+B^2)(1-B+B^2) = (1+B+B^2+B^3+B^4+B^5)$. To obtain an *I(0)* series, i.e. stationarity, one has to differenciate this new transformed series once. To remove *all* unit roots using *one* single filter one has to transform the original series by $(1-B^6) = (1-B)(1+B)(1+B+B^2)(1-B+B^2)$.

where each of the Π_i is an $(N \times N)$ matrix of parameters, D_t are seasonal dummies orthogonal to the constant term μ and $\varepsilon_t \sim niid(0,\Omega)$. The VAR-system of equations in (7) written in error correction form (ECM) is;

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

with $\Gamma_i = -I + \Pi_1 + \ldots + \Pi_i$, $i = 1,\ldots,k-1$. Hence, Π_K is the long-run 'level solution' to (7). If $\mathbf{x}_t$ is a vector of $I(1)$ variables, the left-hand side and the first $(k-1)$ elements of (8) are $I(0)$, and the last element of (8) is a linear combination of $I(1)$ variables. Given the assumption on the error term, this last element must clearly also be $I(0)$; $\Pi_K x_{t-k} \sim I(0)$, hence either $\mathbf{x}_t$ 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 $\mathbf{x}_t$ are stationary. If r=N, the variables in levels are stationary; if r=0 so that Π_K=0, none of the linear combinations are stationary. When 0< r<N , r cointegration vectors, or r stationary linear combinations of $\mathbf{x}_t$ exist. In this case one can factorize Π_K; $-\Pi_K = \alpha\beta'$, where both β and α are $(N \times r)$ matrices, and β contains the cointegration vectors (the error correcting mechanism in the system) and α the adjustment parameters.

Johansen and Juselius show that after undertaking appropriate factorizing and by solving an eigenvalue problem it is possible to test for the number of significant vectors using two different tests, the 'trace' test and the 'maximal eigenvalue' test. The trace test (η_r) is a likelihood ratio test for *at most r cointegrating vectors;* $\eta_r = -T\sum_{i=r+1}^{N} \ln\left(1-\hat{\lambda}_i\right)$, where T is number of observations, and the $\hat{\lambda}_i$ are the eigenvalues that solve the eigenvalue problem. The maximal eigenvalue test (ξ_r), is a test of *the relevance of column* r+1 *in* β; $\xi_r = -T\ln\left(1-\hat{\lambda}_{r+1}\right)$. Critical values for the rank test statistics are tabulated in Johansen (1988) and Johansen and Juselius (1990). Osterwald-Lenum (1992) has calculated rank test statistics in the case of more than 5 variables.

The next step is to test for the significance of the price series in the cointegrating relation (Hamilton, 1994, pp. 648-50). Given a cointegration relationship we impose exclusion tests as null restrictions on the long-run parameters in $\hat{\beta}$. To conclude that products belong to the same market, it is also required that all the parameters in $\hat{\beta}$ are significantly different from zero. For instance, if prices for fresh, frozen and smoked salmon cointegrate and we want to test the significance of smoked salmon, the null hypothesis is; '$H_0: \hat{\beta}_{smoked} = 0$; *the market consists of fresh and frozen salmon only'* against the alternative; *'one common market fxists for all three products'*. If one rejects the null, smoked salmon significantly contributes to the cointegrating relation, and is thus part of the market. Price series which in general have independent processes could be weakly cointegrated if they are exposed to substantial common cost or demand shocks, rather than the economic activities relevant to market delineation such as substitution and arbitrage. In situations where we accept the null, we ascribe the results to such phenomena. Hence, by testing for the individual parameters' significance we ensure that our cointegration relations are more robust. Note that if there is more than one cointegration vector a joint exclusion test requiring all corresponding parameters across the vectors to the be zero has to be performed, e.g. with two cointegration vectors, the null would be; $H_0: \hat{\beta}_{1,smoked} = \hat{\beta}_{2,smoked} = 0$.[15]

To take care of possible linear trends in the variables, the constant term μ serves a dual function. When the series are believed to contain a linear trend the constant term in (5) is partitioned to include also a time trend. The linear trends are treated as common, i.e., they cancel in the cointegration relations. In a model without time trend the constant term will only appear as part of the cointegration vectors, i.e., the ECM representation contains any constant within the term $\Pi_K \mathbf{x}_{t-k}$ only. The significance of a linear time trend is tested for using an ordinary likelihood test (Johansen & Juselius, 1990; Hamilton, 1994).

A problem when analysing price series is the existence of possible underlying common factors. If these dominate the individual variation in the series, one could obtain spurious results by accepting interdependencies erroneously even when utilising deflated price series. In the present

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[15]The null restrictions on the parameters in $\hat{\beta}$ are tested for by using a likelihood ratio test. First one estimates the unrestricted model and solves the eigenvalue problem, then one estimates the model with the restriction(s) imposed and calculates the restricted eigenvalues $\hat{\lambda}_1^* > ... > \hat{\lambda}_r^*$. Finally, one calculates the test statistics given by; $LR^*[r(N-s)] = T\sum_{i=1}^{r} \ln\{1-\hat{\lambda}_i^*/1-\hat{\lambda}_i\}$. The test statistic has an asymptotic chi-square distribution with $r(N-s)$ degrees of freedom, where s is the number of independent cointegration parameters in the restricted model.

case such a common factor could be the general upward movement in the price level. Hence, in addition to deflating the price series, the consumer price index is included in the VAR system as a predetermined variable that is not allowed to enter the cointegration space. Thus, it is treated as a common factor which cancels in the cointegration relations.[16]

2.4. The EU Market(s) for Salmon[17]

Together with Japan and the US, the EU is the most important market for salmon. Norway is the biggest producer of farmed salmon, and exported more than 70% of its production of salmon to the EU during the period 1988 to 1992. Norway, the US and Canada are the three main suppliers of frozen salmon. In the period 1981 to 1992 they accounted on average for more than 80% of the EU market. From being the smallest supplier of the three in 1981, Norway is bigger than the total of US and Canada in 1992. Norway's average market share for the period 1981 to 1984 was 10 %, and the total of the US and Canada 76%. For the period 1988 to 1992 these average shares have changed to 45% and 33%, respectively. For fresh salmon Norway has been the stable main supplier throughout the period, with an average market share of 72%. Norwegian farm-gate sales of salmon were closely regulated until 1991. The Fish Farmers' Sales Organisation (FFSO) was authorised by the government to set minimum prices, promote Norwegian salmon world-wide and collect market information. A government license was required for export until July 1991, and even though there are several of these exporters, the 10 biggest accounted for 59% of total salmon export in 1989-90 (Bjørndal & Salvanes, 1992). Hence, due to the structure and the regulation of this industry several studies have argued that it is reasonable to treat Norway as a *unit* (Herrmann & Lin, 1988a, 1988b; DeVoretz & Salvanes, 1993).[18]

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[16]The results were obtained using a RATS program written by Katarina Juselius (1991), which was kindly made available by Gunnar Bårdsen.

[17]We use monthly data from the EU trade statistics—EUROSTAT for the period October 1980 to December 1992. See Appendix B for precise variable definitions.

[18]The second biggest producer of fresh salmon is Scotland with a share of 10%. The Scottish industry is dominated by multinationals rather than small-scale farms, as in Norway. In 1986 the three biggest Scottish firms accounted for 50% of total Scottish salmon production. Further, the Scottish farmers have voluntary formed their own producer associations. Thus, due to the industry structure one has argued that also Scotland is to be treated as a unit.

There is no natural barriers to arbitrage in the EU. However, since FFSO got very detailed information on destination and prices in the EU, their disciplinary device—the export licence system and the minimum prices, may have been used to encourage the exporters in exercising some price discrimination. An analogous argument may apply also for the European buyers trading with Norway, i.e. they would not exercise arbitrage to sustain a good reputation with FFSO as their main supplier. Hence, it is not obvious that one should treat the EU as one market.

Wild salmon is caught mainly in the two last quarters of the year as opposed to farmed salmon that is supplied throughout the year. Frozen salmon may on the other hand be delivered all year. Hence, we undertake cointegration tests both for frozen and fresh salmon. Frozen and fresh salmon account for about 85% of the EU market for salmon. We focus on six countries/areas here; France, Belgium/Luxembourg, Holland, Germany, UK and Denmark, representing between 86 and 97% of the EU market for fresh and frozen salmon during the period 1981 to 1992 (see Table 1). Thus, the conclusions should be applicable for all the EU.[19] France accounts for approximately 50% of the EU market for frozen salmon, the five others share the remaining 35 to 45% approximately equally between them. France is the dominant market for fresh salmon too, with an average of 37% of the EU market. However, the remaining five are more dispersed, with Germany and Denmark accounting for 19 and 16%, respectively. The market shares of fresh and frozen salmon sold in the EU are shown in Table 1.[20]

We focus on the three main products, fresh, frozen and smoked salmon.[21] Empirical studies have concluded with varying degree of substitutability between fresh and frozen salmon (DeVoretz & Salvanes, 1993, Bjørndal, Salvanes & Andreassen, 1992). Both frozen and fresh salmon are used as inputs in the smoked salmon industry. Hence, the substitution between fresh and frozen salmon takes place on two levels, as inputs in the smoked salmon industry and directly in the

[19] Italy, which is a growing market is left out of the analysis due to missing observations and poor data quality.

[20] There is no noteworthy difference in using market shares based on quantities.

[21] The average market shares for these products in the EU the period 1981 to 1992 were 41, 43, and 16% for fresh, frozen and smoked salmon, respectively. In France, the corresponding numbers were 37, 53 and 9%. Other salmon products, e.g. salted salmon, represent less than 1% of the market. In particular the figures for France underestimate the actual consumption of smoked salmon due to a considerable domestic production. However this does not interfer with our analysis. It is reasonable to regard domestic and imported salmon as perfect substitutes. Hence, the price of domestic smoked salmon cannot depart from the imported smoked salmon price.

Table 1

Fresh and Frozen salmon's market shares (in percentage) in the EU based on FOB value.

	France	Belgium/Luxemb.	Holland	Germany	UK	Denmark	Group Total
				Fresh salmon			
1981	40.6	7.4	2.2	22.6	7.8	19.1	99.7
1982	41.6	7.2	2.8	24.5	8.8	14.4	99.3
1983	38.7	8.4	2.7	23.2	10.8	15.7	99.5
1984	36.3	8.6	3.1	23.0	10.5	16.2	97.7
1985	32.2	8.0	3.2	19.4	10.4	17.8	91.0
1986	38.8	7.9	3.5	18.4	6.7	14.6	89.9
1987	38.3	7.1	3.6	18.1	4.5	15.5	87.1
1988	35.7	6.3	3.1	16.4	4.6	17.3	83.4
1989	36.9	6.3	3.1	15.8	5.0	14.9	82.0
1990	36.5	6.5	3.3	14.6	4.4	14.9	80.2
1991	37.9	6.5	3.6	15.8	2.7	11.5	78.0
1992	35.2	5.7	4.6	15.8	4.4	15.4	81.1
Mean	37.4	7.2	3.2	19.0	6.7	15.6	89.1
				Frozen salmon			
1981	49.4	6.9	4.0	8.5	15.3	13.0	97.1
1982	49.4	6.9	3.2	7.5	13.7	12.9	93.6
1983	51.5	6.7	2.9	8.8	13.8	11.7	95.4
1984	57.4	6.2	3.4	6.0	12.8	10.0	95.8
1985	45.4	5.9	3.2	6.5	12.0	15.8	88.8
1986	52.8	5.2	3.4	6.3	9.9	14.5	92.1
1987	55.4	5.7	3.0	6.6	9.1	13.5	93.3
1988	56.3	4.9	2.4	5.1	7.2	15.4	91.3
1989	56.1	4.6	2.5	7.7	6.9	14.2	92.0
1990	59.3	3.8	1.5	7.5	4.4	16.6	93.1
1991	48.9	3.0	1.5	6.4	4.1	29.9	93.8
1992	45.9	3.6	2.2	10.6	6.2	25.1	93.6
Mean	52.3	5.3	2.8	7.3	9.6	16.1	93.3

market as final consumption goods. On the other hand, the consumers may perceive differences in quality between fresh and frozen salmon, and smoked salmon is not consumed in the same way as the other two products. An argument for an integrated market could be that since the three products are parts of the same production chain *and* it is easy to switch between the products, the supply side will determine some common trend in the price development—and thus force them towardsuniformity.[22] However, the decision of whether to sell the salmon as fresh or frozen is

[22]There is of course an asymmetry here in the sense that they can only switch in one direction, i.e. from fresh to frozen, or from fresh and frozen to smoked.

done before the fish arrive at the market. Hence, taken together the picture is ambiguous and there are no clear-cut arguments for *one* versus *two* or *three* markets.

As argued in section 3, in this industry seasonal variation is important. Since higher aggregation level often reduces seasonality and gives smoother series, we want to test whether aggregation levels alter our conclusions when we test for the product dimension. Hence, we do the analysis at two aggregation levels—France and the EU. There are several reasons to choose France. France is the biggest importer of salmon in the EU and has the largest salmon processing industry. Further, several demand studies on salmon have been undertaken for this market.

2.5. Seasonality and Integration Order

By applying the BM-test presented in section 3.1, we test the order of integration at the long-run zero frequency and the possible existence of seasonal unit roots. Sixteen price series are tested, prices for fresh, frozen and smoked salmon in France and the EU, and prices for fresh and frozen salmon in Belgium/Luxembourg, Holland, Germany, UK and Denmark (see Appendix B for a precise variable definition).

A problem often discussed is the necessity of a long data series to detect eventual long-run properties. Several studies have addressed this question for unit root and cointegration tests (Hakkio & Rush, 1991; Perron, 1989; Shiller & Perron, 1985). The results suggest that the relevant factor to discuss is the length of the total sample period relative to the length of the long run in the data. The usual interpretation of short run is the period wherein some factors cannot be changed. The salmon production is based on a biological process. The production cycle in farming, starting from the time the smolts are put into the water until the time the salmon are ready to be harvested and sold in the marketplace lasts for roughly two years. Hence, it is reasonable to determine the long run as the length of time it takes to produce a farmed salmon; approximately two years. Hakkio and Rush (1991) conclude that if the long run is relatively short, e.g. like here, 1-2 years, their Monte Carlo simulations suggest that higher frequency, i.e., using quarterly or monthly data, improves the tests ability to uncover the long run properties of the data series. Here we have 13 years of information, which actually represent the "whole history" in this market, in the sense that prior to 1980 the EU market for salmon was very small and the farmed salmon industry was neglectible. None of these small sample studies use multivariate techniques, or as rich unit root test specification as the one used here. The multivariate tests are stronger due to more independent variables (information) present in the tests, and the seasonal integration test has more power in the presence of seasonal data than the standard unit root tests. Hence, we should be able to trace the long run properties in the present problem.[23]

The estimated auxiliary equations are all of the form in (6), where x_t is the corresponding price series in log form, and $y_{k,t}$ are the seasonal differences of the series.[24] Hence, we account for deterministic seasonality by including seasonal dummies and a constant term. The set of lags necessary to account for autocorrelation—$\varphi(B)^*$, is determined by first estimating (6) with 36 and 24 lags, and then excluding those that fail to enter significantly at the 15% level. Then we use the information criterion due to Schwarz and restrict the number of lags until the Schwarz information criterion reaches its local minimum and the Ljung-Box Q-statistics show no autocorrelation of higher order (Ljung & Box, 1979; Schwarz, 1978). This approach is chosen to trade off the loss of power that results from including too many lags against the bias that results from excluding necessary lags.

Using the BM-approach, we found seasonal unit roots in six series, all the price series for France, the price series for frozen salmon in Holland and Germany, and the price series for fresh salmon in the UK.[25] The results from the tests are presented in Table 2 through 4. The cycles 2 and 10 ($H_0: \pi_7 = \pi_8 = 0$) are present in two series, France(frozen) and France(smoked), the cycle 6

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[23]Hakkio and Rush (1991) found that the bias in small samples went in the direction of rejecting cointegration too often. When accepting cointegration in small samples their Monte Carlo simulations suggested *'a fairly strong conclusion'*.

[24]However, we omit the time trend, something which also is concluded when testing for cointegration in the next section (see footnote 27). The inclusion of linear trend in (6) has the same interpretation as in a standard Dickey Fuller test, i.e. a positive (negative) time trend could be interpreted as non constant growing (decreasing) variance.

[25]The BM procedure is sensible to sample size. By using Monte Carlo simulations Beaulieu & Miron find that in small samples their test could be biased in the sense of too often accepting the null-hypothesis of seasonal unit roots ($\pi_k = 0$). Hence, we accept existence of seasonal unit roots only if we cannot reject them even at a 10% significance level. The critical values in Beaulieu and Miron are based on n=240, and are therefore too high in absolute value compared to our smaller sample. For instance, if we compare our results with the critical F-values tabulated by Franses (1990) for n=120, we reject $H_0: \pi_{11} = \pi_{12} = 0$ for frozen salmon in France also at a 5% significance level.

Table 2

Results from testing for seasonal unit roots using BM-tests (equation 6) for the price series in France and the EU.[1]

	France			EU		
	Fresh	Frozen	Smoked	Fresh	Frozen	Smoked
t-statistics						
$\pi_1 = 0$	-0.61	-1.07	-0.69	-0.59	-0.15	-2.24
$\pi_2 = 0$	-2.09	-4.96*	-2.79*	-3.34*	-2.55**	-5.18*
$\pi_3 = 0$	-2.40	-6.23*	-4.78*	-4.93*	-3.53*	-4.18*
$\pi_4 = 0$	-3.33*	-0.96	0.03	-2.00*	-2.41*	-1.74**
$\pi_5 = 0$	-4.13*	-3.19**	-3.48*	-5.13*	-4.93*	-3.48*
$\pi_6 = 0$	2.18*	-1.64**	-1.17	1.32	1.47**	0.51
$\pi_7 = 0$	-2.76	-3.07**	-2.24	-3.14**	-2.49	-3.62*
$\pi_8 = 0$	-4.44*	-0.15	-0.07	-3.63*	-2.57*	0.93
$\pi_9 = 0$	-3.80*	-3.37*	-4.48*	-4.66*	-4.30*	-4.40*
$\pi_{10} = 0$	2.03*	1.16	-1.09	2.15*	0.72	0.52
$\pi_{11} = 0$	-2.16	-3.22**	-4.25*	-3.19**	-2.86	-5.98*
$\pi_{12} = 0$	-4.10*	0.77	-2.74*	-4.03*	-3.12*	0.93
F-statistics						
$\pi_3 = \pi_4 = 0$	9.54*	20.41*	11.40*	15.84*	9.57*	9.95*
$\pi_5 = \pi_6 = 0$	11.73*	6.87*	6.92*	14.52*	12.66*	6.49*
$\pi_7 = \pi_8 = 0$	15.88*	4.89	2.52	13.25*	8.59*	7.13*
$\pi_9 = \pi_{10} = 0$	9.61*	7.23*	11.36*	13.61*	10.11*	10.98*
$\pi_{11} = \pi_{12} = 0$	9.58*	6.08**	14.01*	12.06*	7.07*	17.96*

*/ Significant at the 5% level, **/ significant at the 10% level. We use critical values from Beaulieu and Miron (1993).

[1]/ The polynomials $\varphi(B)^*$ are; France(fresh) $(1-B^3)$, France(frozen) $(1-B-B^4-B^5-B^{11}-B^{15})$, France(smoked) $(1-B^6-B^{18})$, EU(fresh) $(1-B^3)$, EU(frozen) $(1-B^4-B^6-B^{12}-B^{15}-B^{16})$, EU(smoked) $(1-B^2-B^4-B^5-B^7-B^9-B^{12}-B^{14}-B^{21}-B^{24})$. The Ljung-Box statistics (Q(12), Q(24), Q(36)) show no autocorrelation in any of the regressions.

Table 3

Results from testing for seasonal unit roots using BM-tests (equation 6) for the price series for frozen salmon in France, Belgium/Luxembourg, Holland, Germany, UK and Denmark.[1]

	Frozen salmon					
	France	Belgium/ Luxemb.	Holland	Germany	UK	Denmark
t-statistics						
$\pi_1 = 0$	**-1.07**	**-1.28**	**-0.45**	**-1.17**	**-1.28**	**0.27**
$\pi_2 = 0$	-4.96*	-3.29*	-3.24*	**-2.30**	-2.86*	-4.69*
$\pi_3 = 0$	-6.23*	-3.65*	-4.71*	-3.91*	-4.17*	-4.85*
$\pi_4 = 0$	-0.96	-0.84	-3.41*	-0.54	-0.60	-0.004
$\pi_5 = 0$	-3.19**	-4.66*	-3.90*	-4.02*	-5.29*	-5.52*
$\pi_6 = 0$	-1.64**	-0.77	2.76*	0.71	0.25	-0.60
$\pi_7 = 0$	-3.07**	-4.12*	-3.90*	-3.26*	-3.89*	-5.00*
$\pi_8 = 0$	-0.15	-1.56**	-2.41*	-1.20	-1.83	0.68
$\pi_9 = 0$	-3.37*	-6.22*	-4.76*	-4.90*	-3.60*	-6.11*
$\pi_{10} = 0$	1.16	0.27	1.31	0.54	1.90	-1.15
$\pi_{11} = 0$	-3.22**	-0.98	-2.32	-3.38*	-2.92	-3.90*
$\pi_{12} = 0$	0.77	-3.81*	-0.64	-2.19	-2.48*	-1.02
F-statistics						
$\pi_3 = \pi_4 = 0$	20.41*	7.52*	16.67*	7.83*	8.98*	12.46*
$\pi_5 = \pi_6 = 0$	6.87*	11.16*	11.26*	8.46*	14.11*	15.40*
$\pi_7 = \pi_8 = 0$	**4.89**	9.96*	11.61*	6.17**	9.84*	12.53*
$\pi_9 = \pi_{10} = 0$	7.23*	19.60*	12.02*	12.18*	9.13*	18.70*
$\pi_{11} = \pi_{12} = 0$	6.08**	8.35*	**3.56**	8.61*	8.07*	8.00*

*/ Significant at the 5% level, **/ significant at the 10% level. We use critical values from Beaulieu and Miron (1993).

[1]/ The polynomials $\varphi(B)^*$ are: France $(1-B-B^4-B^5-B^{11}-B^{15})$, Belgium/Luxembourg $(1-B^8-B^{11})$, Holland $(1-B)$, Germany $(1-B^{16})$, UK $(1-B^{17}-B^{26})$ and Denmark $(1-B^{11}-B^{12}-B^{23}-B^{24})$ The Ljung-Box statistics (Q(12), Q(24), Q(36)) show no autocorrelation in any of the regressions.

Table 4

Results from testing for seasonal unit roots using BM-tests (equation 6) for the price series for fresh salmon in France, Belgium/Luxembourg, Holland, Germany, UK and Denmark.[1]

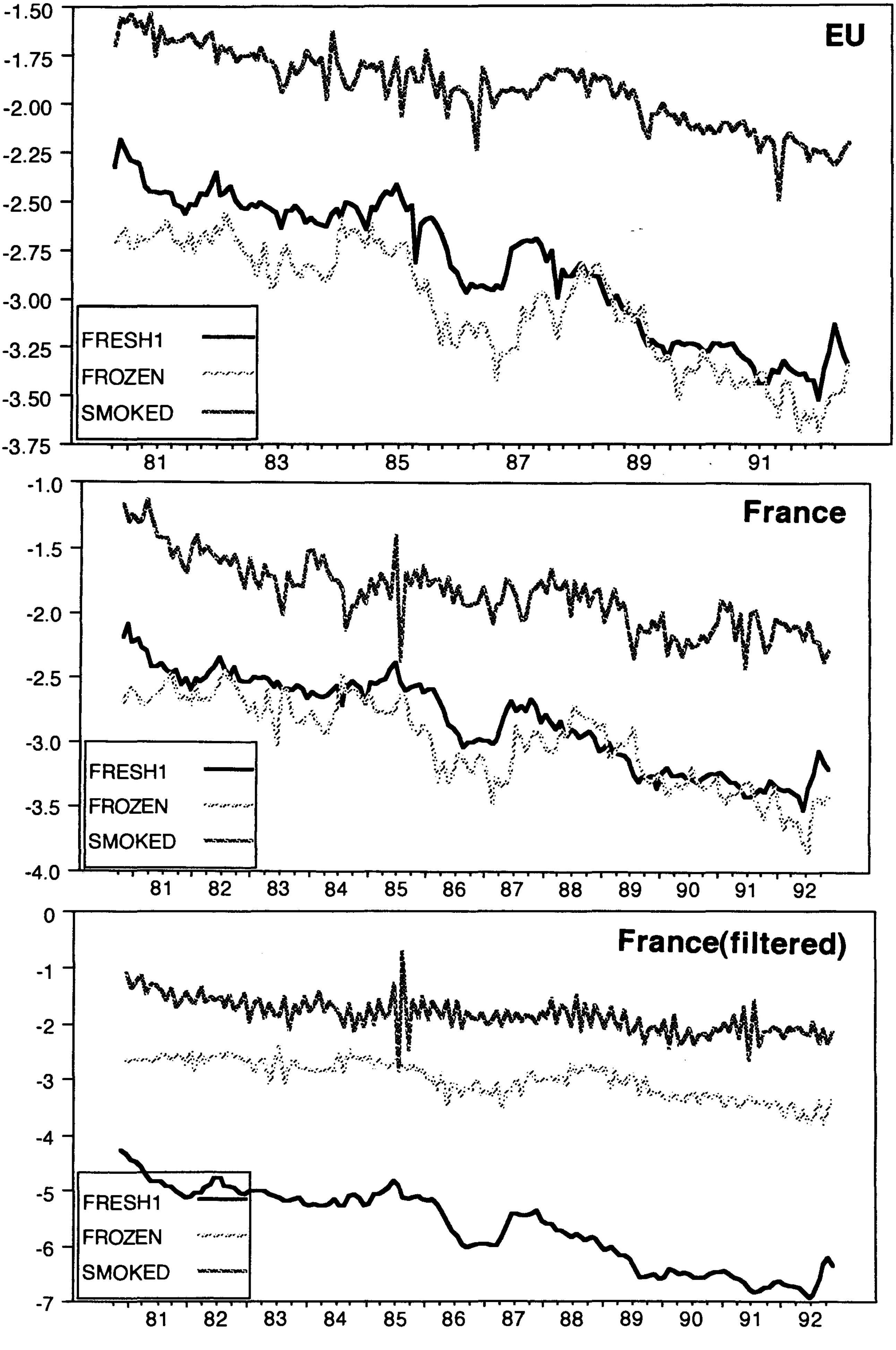
	Fresh salmon					
	France	Belgium/ Luxemb.	Holland	Germany	UK	Denmark
t-statistics						
$\pi_1 = 0$	**-0.61**	**-0.72**	**-0.68**	**-0.63**	**-0.02**	**-1.16**
$\pi_2 = 0$	**-2.09**	-3.28*	-3.03*	-2.99*	**-0.51**	-3.61*
$\pi_3 = 0$	-2.40	-2.98**	-4.16*	-2.94	-2.66	-2.94
$\pi_4 = 0$	-3.33*	-4.43*	-2.59*	-4.46*	-2.66*	-2.38*
$\pi_5 = 0$	-4.13*	-4.84*	-4.62*	-3.84*	-3.06**	-4.54*
$\pi_6 = 0$	2.18*	-1.58**	1.71**	1.94*	1.85*	1.79**
$\pi_7 = 0$	-2.76	-3.26*	-3.44*	-2.66	-3.46*	-0.82
$\pi_8 = 0$	-4.44*	-3.93*	-4.21*	-3.46*	-2.13*	-3.77*
$\pi_9 = 0$	-3.80*	-3.52*	-4.32*	-3.50*	-4.28*	-5.00*
$\pi_{10} = 0$	2.03*	0.34	-0.52	0.83	0.52	1.73**
$\pi_{11} = 0$	-2.16	-3.87*	-2.94	-2.76	-3.17**	-2.42
$\pi_{12} = 0$	-4.10*	-4.67*	-3.71*	-4.00*	-1.92*	-3.32*
F-statistics						
$\pi_3 = \pi_4 = 0$	9.54*	15.58*	13.24*	16.01*	7.88*	7.88*
$\pi_5 = \pi_6 = 0$	11.73*	13.50*	12.33*	10.07*	6.82*	12.44*
$\pi_7 = \pi_8 = 0$	15.88*	14.57*	18.51*	11.63*	9.16*	7.67*
$\pi_9 = \pi_{10} = 0$	9.61*	6.29*	9.44*	6.57*	9.44*	14.69*
$\pi_{11} = \pi_{12} = 0$	9.58*	15.44*	10.27*	10.79*	8.59*	9.05*

*/ Significant at the 5% level, **/ significant at the 10% level. We use critical values from Beaulieu and Miron (1993)

[1]/ The polynomials $\varphi(B)^*$ are; France $(1-B^3)$, Belgium/Luxembourg $(1-B^5)$, Holland $(1-B^4)$, Germany $(1-B^5)$, UK $(1-B^9-B^{20}-B^{21}-B^{23}-B^{24}+B^{35})$ and for Denmark we used no lags. The Ljung-Box statistics (Q(12), Q(24), Q(36)) show no autocorrelation in any of the regressions.

Figure 1

Prices of salmon in France and the EU deflated with the consumer price index (in logarithm), filtered and unfiltered series.



($H_0: \pi_2 = 0$) is present in three series, France(fresh), UK(fresh) and Germany(frozen), and finally, the cycles 1 and 11 ($H_0: \pi_{11} = \pi_{12} = 0$) are present only in the series Holland(frozen) (see Table A1, Appendix A). Due to the importance of biological factors in the production technology, and demand driven seasonality, we find the results of stochastic seasonality reasonable.

In earlier analyses using the HEGY or BM approach, one typically analysed aggregated macro series and verifies some changing seasonal pattern; seasonal unit roots. We find that the less aggregated the series are, the more likely we are to find seasonal unit roots. The BM test reveals no significant seasonal unit roots at the aggregated EU level. One explanation could be that the three disaggregated series for frozen salmon have all different roots, implying no common seasonal factor. For fresh salmon we find the same seasonal unit roots, however, they appear only in two series. This is in accordance with what Hylleberg *et al* (1991) conclude when splitting real Gross Domestic Product in various sectors and test for seasonality, they find *more*, and more *distinct* seasonal unit roots in the disaggregated series.[26] However, their study is also at a quite high aggregation level. Hence, our results indicate that the importance of accounting for the problem of stochastic seasonality may be even higher when dealing with micro data.

We accept the hypothesis of unit root at the long-run zero frequency ($H_0: \pi_1 = 0$) for all the price series—the series are non-stationary in their levels. We test for integration order by running the BM-test, but now x_t in (6) are the first differences of the price series. The tests conclude stationarity at the zero frequency at reasonable significance levels for all series, i.e. stationary in the differences—the series are $I(1)$. Thus, the series could all be used as variables in the cointegration analysis, where one searches for linear combinations of $I(1)$ variables that are $I(0)$.

To remove as much noise as possible in the cointegration tests we now filter the series for stochastic seasonality, leaving only the long-run zero frequency. Since the tests have verified only one or two seasonal cycles in each series this is quite straightforward using equation (5) and Table A1, Appendix A. For instance, the filter necessary to remove 6 cycles ($\pi_2 = 0$) is given as the second parenthesis at the RHS in (5); $(1+B)$. We summarise the filters and results in Table 5. To

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[26]Hylleberg *et al* (1991) analyse Gross Domestic Product sectors for four countries, Austria, Finland, Germany and Greece and for all they find seasonal unit roots for the agricultural sector.

illustrate the effect of filtering, we have graphed the series for France and the EU in Figure 1.

Table 5

Seasonal unit roots, cycles, frequencies and filters for the series UK(fresh), France(fresh), France(smoked), France(frozen), Holland(frozen) and Germany(frozen).

	Seasonal Unit Roots	Seasonal Cycles	Seasonal frequencies	Filters used
UK(fresh)	$\pi_2 = 0$	6	π	$(1+B)$
France(fresh)	$\pi_2 = 0$	6	π	$(1+B)$
France(smoked)	$\pi_7 = \pi_8 = 0$	2, 10	$\pi/3, \ -\pi/3$	$(1-B+B^2)$
France(frozen)	$\pi_7 = \pi_8 = 0$	2, 10	$\pi/3, \ -\pi/3$	$(1-B+B^2)$
Holland(frozen)	$\pi_{11} = \pi_{12} = 0$	1, 11	$\pi/6, \ -\pi/6$	$(1-\sqrt{3}B+B^2)$
Germany(frozen)	$\pi_2 = 0$	6	π	$(1+B)$

2.6. Cointegration Results

In the first section we focus on the product space, testing for cointegration between fresh, frozen and smoked salmon. Section 6.2, focuses on the geographic space, where tests for cointegration between the six countries/areas in the EU are undertaken. All cointegration tests are done both with unfiltered and filtered data.[27]

2.6.1. The Product Space

In section 5 all the price series from France were found to be seasonally integrated. We do three parallel multivariate cointegration tests, two for France (unfiltered and filtered), and one for the EU, where none of the variables were found to be seasonal integrated. Hence, the matrix of variables in

[27] All tests are done both with a linear trend imposed and without. The restriction of no trend is accepted in all models significantly. Hence, all the results presented here are based on VAR-models with no linear trend and an intercept term in each cointegration vector.

(8), $\mathbf{x}_t$, consists of the three deflated price series, fresh, frozen and smoked salmon in logarithms, i.e. $\mathbf{x}_t = \left[x_{t,FH}, x_{t,FZ}, x_{t,SM}\right]$. In addition to seasonal dummy variables, is the monthly consumer price index included in (8) as a predetermined variable.[28] The maximal eigenvalue test (ξ_r) and the trace test (η_r) based on the VAR system in (8) are tabulated in Table 6.[29] For all three cases we find at least one significant cointegration vector, indicating an integrated market. For the EU the test concludes with two cointegration vectors. The result based on the filtered French price series is moving in direction of the EU result in the sense of providing higher test statistics for the test of two cointegration vector(s). Hence, the seasonal filtering removes noise and provides clearer results.

Table 6

Multivariate cointegration tests based on the VAR system in (8), critical values η_r and ξ_r—The Product Space.

	France (unfiltered)		France (filtered)		EU	
	ξ_r	η_r	ξ_r	η_r	ξ_r	η_r
1 coint. vec $r=0$	28.73*	43.51*	25.69*	41.31*	19.54 †	42.64*
2 coint. vec $r=1$	11.53	14.78	12.57	15.63	14.91***	23.11*
3 coint. vec $r=2$	3.25	3.25	3.05	3.05	8.19	8.19

*/ Significant at a 2.5% level, **/ significant at a 5% level, ***/ significant at a 10% level.
† The critical value for one cointegration vector in the maximum eigenvalue test at a 10% level, is 19.77 (Osterwald-Lenum, 1992). Hence, the test statistics; ξ_r=19.54, is nearly significant.

The next step is to test for the significance of the price series in these cointegration relationships. This is done by implementing null-restrictions on the long run parameters in $\hat{\beta}$, and employing exclusion tests (for estimation details see Johansen & Juselius, 1990 and Hamilton, 1994). The likelihood statistics are shown in Table 7. For France all long run parameters are significantly different from zero at a 2.5% level. For the EU we find the same for fresh and frozen, but could

[28]The French consumer price indexes is from IMF's International Financial Statistics, the EU consumer price index is from OECD (1985=100).
[29]Twelve lags in (8) were enough to account for autocorrelation ($k = 12$).

reject the null hypothesis for smoked only at a 10% level. However, the overall interpretation of the test statistics leads us to believe that smoked salmon belongs to the cointegration relation too. Hence, statistically we have verified a robust long-run cointegration relationship between the prices for fresh, frozen and smoked salmon—there is a unique long-run equilibrium relationship in which deviations from product price parity are forced to zero.

Table 7

Exclusion tests—The Product Space.

	France (unfiltered) $r(N-s)=1(4-3)=1$	France(filtered) $r(N-s)=1(4-3)=1$	EU $r(N-s)=2(4-3)=2$
$H_0:\beta_{j,FH}=0$	14.50*	7.77*	8.41*
$H_0:\beta_{j,FZ}=0$	7.58*	11.86*	10.66*
$H_0:\beta_{j,SM}=0$	13.51*	6.06*	4.75***

*/significant at a 2.5% level, ***/significant at a 10% level

Bivariate cointegration tests are also undertaken for these series. However, the bivariate results are more ambiguous. In the 9 tests, only 6 conclude cointegration vectors at a 10% significance level, and only 4 at a 5% level. Hence, by restricting the test to pairwise comparisons one omits important information, and are thus less likely to reveal the long-run relationship. This stresses the importance of using the multivariate technology when dealing with more than two markets (refer discussion in section 2). Also here the filtering reduces noise and provides clearer results.[30]

What is the economic rationale for our result—statistically existence of a long-run equilibrium? As argued in section 4, substitution, as well as supply-side characteristics, could be used to support such a result. Further, the fact that fresh and frozen salmon are substitutes both in the production process of smoked salmon, and as final consumption goods may explain why the exclusion tests indicate weaker price interdependencies only for smoked salmon.

[30]The bivariate results are available upon request to the author.

2.6.2. The Geographic Space

We use the same VAR system as in the last section, but now we have six price series; $\mathbf{x}_t = \left[x_{t,F}, x_{t,BLX}, x_{t,NL}, x_{t,G}, x_{t,UK}, x_{t,DK}\right]$, where the abbreviations represent France, Belgium/-Luxembourg, Holland, Germany, United Kingdom and Denmark. All the prices are in logarithm, deflated by the respective monthly consumer price indexes.[31] We start by analysing the price series for frozen salmon.[32] Two tests are undertaken, one only using unfiltered data, and one using a combination of filtered (France, Holland and Germany) and unfiltered data (Luxembourg/Belgium, UK and Denmark). The Maximal eigenvalue and Trace tests are shown in Table 8. Both tests provide clear evidence for cointegration. However, when using the unfiltered data the maximal eigenvalue and trace tests conclude with different number of cointegration vectors. The maximal eigenvalue test concludes with two vectors at 2.5% significance level, as opposed to the trace test, that concludes with four vectors at a 5% level. The maximal eigenvalue test is regarded as the most credible test (Johansen & Juselius, 1990). Hence, we conclude with three cointegration vectors. The cointegration test based on the combination of filtered and unfiltered data is very clear, where both the trace test and the maximal eigenvalue test conclude with three vectors at a 2.5% significance level. One explanation for the ambiguity in the tests using the unfiltered data may be the noise made by the stochastic seasonal processes represented in three of the price series.[33]

The next step is to undertake the exclusion tests. The likelihood statistics are presented in Table 9. When using unfiltered data all the price series belong to the cointegration relationship at a 5% significance level. However, using the combined data we find two things: France *disappears* from the cointegration relation, and secondly, the other prices increase their significance in the sense

[31]For Belgium and Luxembourg we have used the Belgian consumer price index. The two consumer price indexes used to represent the predetermined common factor is a Laspeyres index based on the countries' individual consumer price indexes weighted with the value of frozen and fresh salmon sold in each country, (January, 1985=100). All the country indexes are from IMF's International Financial Statistics. The indexes are computed using the econometric packages SHAZAM (White, 1978).

[32]The observation for frozen salmon in Belgium/Luxembourg is missing in December 1992 . Hence, the tests for frozen salmon are based on the period 1980:10 to 1992:11.

[33]If one looks at the correlation between the price series, one finds that even though 5 out of 30 correlation coefficients are lower than .15, and not more than 10 out of 30 are higher than .70, the price series cointegrate in the long run. Hence, there is considerable short term dynamics present in the development of these series.

Table 8
Multivariate cointegration tests for frozen salmon based on the VAR system in (8), critical values η_r and ξ_r—The Geographic Space.

	Unfiltered		Combined	
	ξ_r	η_r	ξ_r	η_r
1 cointegration vector r=0	59.03*	159.39*	51.14*	147.72*
2 cointegration vectors r=1	41.59*	100.36*	38.28*	96.58*
3 cointegration vectors r=2	23.58	58.77*	31.72*	58.30*
4 cointegration vectors r=3	18.57	35.20**	10.85	26.58
5 cointegration vectors r=4	10.11	16.63	10.21	15.73
6 cointegration vectors r=5	6.52	6.52	5.53	5.53

*/ Significant at a 2.5% level, **/ significant at a 5% level, ***/ significant at a 10% level.

Table 9
Exclusion tests for frozen salmon —The Geographic Space.

	$H_0{:}\beta_F = 0$	$H_0{:}\beta_{BLX} = 0$	$H_0{:}\beta_{NL} = 0$	$H_0{:}\beta_G = 0$	$H_0{:}\beta_{UK} = 0$	$H_0{:}\beta_{DK} = 0$
Unfiltered	9.04**	12.42*	21.85*	25.56*	9.53*	9.23**
Combined	5.57	11.04*	17.82*	23.97*	12.94*	25.35*

*/significance at a 2.5% level, **/significance at a 5% level, 3 degrees of freedom; $r(N-s) = 3(7-6) = 3$.

that now all five *belong* to the cointegration relation at a 2.5% level. Thus, as we remove the noise due to stochastic seasonality, we find two EU markets for frozen salmon, one in France and one aggregate market consisting of the remaining EU countries. France has the lowest significance level also when using the unfiltered series.

Before discussing the economic rationale behind this result, we analyse fresh salmon. Here, the combined series consist of the filtered series from France and UK and the four remaining price series that are unfiltered. The maximal eigenvalue and trace test statistics are tabulated in Table 10, and the exclusion tests in Table 11. Five cointegration vectors are found using the unfiltered series. Using the combined series we find three vectors at a 2.5% level, and 4 at a 10% level (using the less credible trace test we find 4 vectors also at a 2.5% level). Hence, we undertake exclusion tests both assuming 3 and 4 cointegration vectors for the combined series. The same pattern is found as for frozen is found, but now it is more ambiguous. The test statistics for France are lowest both for the unfiltered and the combined series. Further, when using combined data and assuming three cointegration vectors we reject the null; *exclusion of France,* only at a 10% significance level. Hence, the tests conclude one EU market for fresh salmon, but provide also weak evidence for France being a separate market.

Table 10

Multivariate cointegration tests for fresh salmon based on the VAR system in (8), critical values η_r and ξ_r—The Geographic Space.

	Unfiltered		Combined	
	ξ_r	η_r	ξ_r	η_r
1 cointegration vector $r=0$	65.75*	183.00*	60.81*	168.47*
2 cointegration vectors $r=1$	38.32*	117.24*	34.61**	107.67*
3 cointegration vectors $r=2$	34.23*	78.93*	31.70*	73.06*
4 cointegration vectors $r=3$	22.05**	44.70*	21.48***	41.36*
5 cointegration vectors $r=4$	16.15**	22.65*	14.98	19.87***
6 cointegration vectors $r=5$	6.50	6.50	4.89	4.89

*/ Significant at a 2.5% level, **/ significant at a 5% level, ***/ significant at a 10% level.

Table 11
Exclusion tests for fresh salmon —The Geographic Space.

	$H_0:\beta_F = 0$	$H_0:\beta_{BLX} = 0$	$H_0:\beta_{NL} = 0$	$H_0:\beta_G = 0$	$H_0:\beta_{UK} = 0$	$H_0:\beta_{DK} = 0$
Unfiltered (5 vectors)	21.23*	38.20*	44.58*	24.83*	33.96*	28.64*
Combined (4 vectors)	12.52*	30.66*	31.79*	18.97*	22.09*	20.70*
Combined (3 vectors)	7.40**	28.18*	26.16*	12.47*	16.92*	15.16*

*/significance at a 2.5% level, **/significance at a 10% level with 3, 4 and 5 degrees of freedom; $r(N-s)=r(7-6)$, $r=5,4,3$.

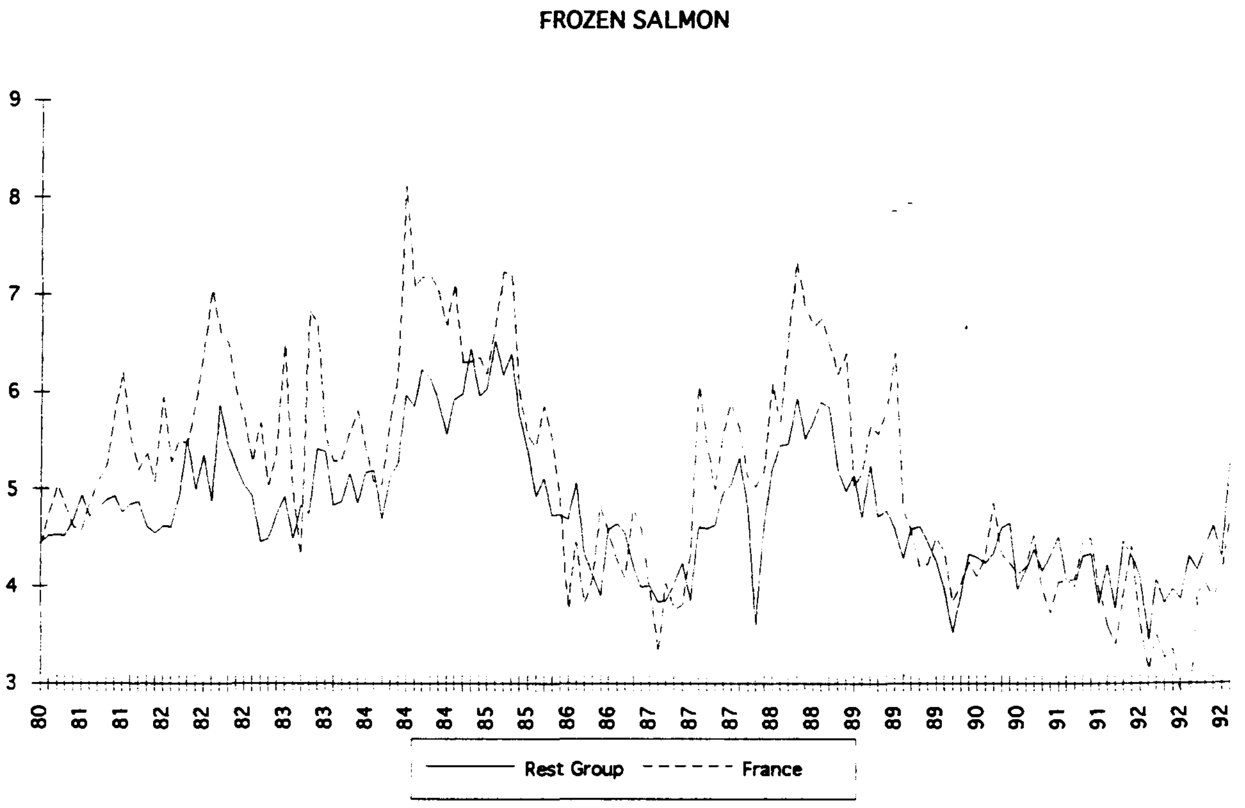
Brought together, the tests conclude France to be different, in particular for frozen salmon. The idea that France is a separate market has some support in the empirical literature, where one divides the salmon market into sub markets (DeVoretz & Salvanes, 1993; Herrmann & Lin, 1988a; 1988b). For instance, DeVoretz and Salvanes (1988) argued that France is a primary market with a higher mark-up price than the rest of the world. We argued in section 4 that the Norwegian Fish Farmers' Sales Organisation may have had some possibility to exercise price discrimination, due to their dominant role in the distribution system. However, we would have anticipated this effect to be largest for fresh salmon, since Norway is more exposed to competition in the market for frozen salmon (the US and Canada). Hence we are reluctant to ascribe our results to strategic price discrimination.

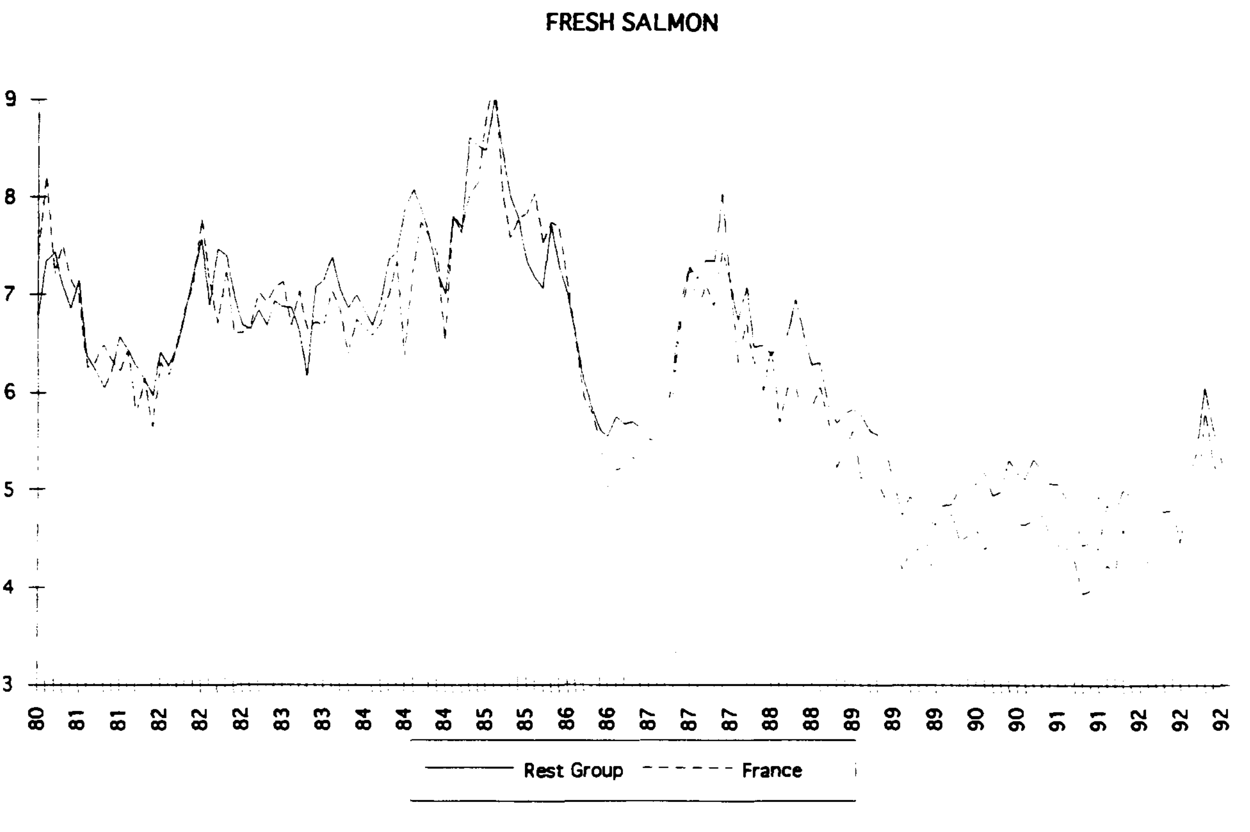
France has a large salmon processing industry, and then in particular a considerable smoked salmon industry. Of total smoked salmon consumed in France, between 70 and 80% is domestically produced (Monfort, 1992).[34] The smoked salmon industry needs stable supplies of high quality inputs. To ensure this, several large French smoked salmon firms have long term contracts with Norwegian exporters. Market surveys of the French market for salmon have indicated that firms with these contracts are more satisfied with the Norwegian quality than their competitors buying in the spot market (Reintz *et al.* 1992; 1994). To obtain these contracts they may have been willing to pay a '*security of high quality supplies* ' premium, thus explaining why France turns out to be a

[34]France is also the largest importer of smoked salmon in the EU. In 1989 the French import amunted to 28% of the EU import of smoked salmon.

Figure 2

Average unit prices of frozen and fresh salmon in France and the aggregated rest group; Belgium/Luxembourg, Holland, Germany, UK and Denmark, 1980-92.





separate market. In Figure 2 we have graphed the average unit prices for fresh and frozen salmon in France and the aggregated rest group. It is interesting to note that before the end of 1989 the price for frozen salmon in France is generally above the price in the aggregate group, indicating such a '*security of high quality supplies* ' premium. In early 1990, Norway started a huge freezing program for salmon to reduce the supply of fresh salmon in the international market. Hence, from 1990 there were large amounts of frozen salmon in stock in Norway, and no reason for the French smoked salmon industry to pay a premium. Hence, the Norwegian freezing program provides an explanation for why the price differential disappears in 1990. Since frozen salmon dominates as input in the smoked salmon industry, this explains also why we do not find the same picture for fresh salmon.

In conclusion, both structural as well as statistical evidence suggest France to be different, representing a separate market for frozen salmon. However, the EU market for fresh salmon seems to be more integrated, exhibiting a more stable long-run relationship.

2.7. Conclusions

We propose the use of Johansen and Juselius' multivariate cointegration methodology as a market delineation tool. The importance of accounting for stochastic seasonality when applying cointegration analysis with seasonal data is also addressed. When testing for long-run relationship one is basically interested in the long-run zero frequency processes. However, stochastic seasonality may act as noise in the variables, making the cointegration methodology less able to reveal possible long-run relationship. Here, we exploit Beaulieu & Miron's test for seasonal integration feature of distinguishing between different seasonal unit roots. We test for seasonal integration, and based on the results appropriate filters are calculated to extract possible seasonal unit roots, leaving only the long-run zero frequency processes. Then the new filtered series are used as inputs in the cointegration tests.

We analyse the EU market for salmon, focusing both on the product space and the geographic space. The tests provide evidence for fresh, frozen and smoked salmon to be in the same market. The geographic tests are more ambiguous, suggesting two different geographic markets for frozen salmon in EC; one single market in France, and the rest of the EU as an aggregated group. The market for fresh salmon is found to be more integrated, i.e. one EU market for fresh salmon. The six countries/areas included represent between 86 and 97% of the EU market for salmon in the analysed period. Hence, the conclusions should be applicable to all of the EU.

The way seasonality is treated in this analysis is new, both in the literature on market delineation and the more general literature on cointegration and seasonality. Empirically our analysis provides support for this seasonality approach. Typically, the cointegration tests provide clearer test statistics when stochastic seasonality is accounted for.

Aggregation level is found to be important when testing for seasonal unit-roots. At the aggregated EU level we find no seasonal unit-roots for any of the series, but at the country level several series are found to have seasonal unit-roots. Thus, when using micro-data it is even more important to account for stochastic seasonality, than in macro analyses where this methodology has been used earlier.

The cointegration methodology is mainly a statistical framework, and is only useful in a proper setting—something it has in common with all time-series methods used in market delineation. As Schrank & Roy (1991, p. 107) put it; '*Markets cannot be defined in a vacuum; market definitions make sense only in the context in which the questions are posed*' However, based on the econometric results found here, we conclude that used with care, the cointegration methodology is a helpful tool in market delineation.

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Appendix 2A: The Beaulieu & Miron Test

Calculating the remaining 8 complex roots (5) could be written as:

$$(A1)\ \left(1-B^{12}\right)=(1-B)(1+B)(1-iB)(1+iB)$$
$$\left(1+(i\sqrt{3}+1)\frac{B}{2}\right)\left(1-(i\sqrt{3}-1)\frac{B}{2}\right)\left(1-(i\sqrt{3}+1)\frac{B}{2}\right)\left(1+(i\sqrt{3}-1)\frac{B}{2}\right)$$
$$\left(1+(\sqrt{3}+i)\frac{B}{2}\right)\left(1+(\sqrt{3}-i)\frac{B}{2}\right)\left(1-(\sqrt{3}+i)\frac{B}{2}\right)\left(1-(\sqrt{3}-i)\frac{B}{2}\right)$$

where the last 11 parentheses correspond to seasonal unit roots, and the first to the long run zero frequency unit root.[A35] All of the seasonal roots correspond to different cycles per year with corresponding frequencies.[A36] The roots, cycles and frequencies are tabulated in Table A1

Table A1.
Roots and the corresponding cycles and frequencies of the polynomial $(1-B^{12})$.

No.	Root	Cycles	Frequency
1	1	0	0
2	-1	6	π
3	$+i$	3	$\pi/2$
4	$-i$	9	$-\pi/2$
5	$-\frac{1}{2}(1+\sqrt{3}i)$	8	$-2\pi/3$
6	$-\frac{1}{2}(1-\sqrt{3}i)$	4	$2\pi/3$
7	$\frac{1}{2}(1+\sqrt{3}i)$	2	$\pi/3$
8	$\frac{1}{2}(1-\sqrt{3}i)$	10	$-\pi/3$
9	$-\frac{1}{2}(\sqrt{3}+i)$	7	$-5\pi/6$
10	$-\frac{1}{2}(\sqrt{3}-i)$	5	$5\pi/6$
11	$\frac{1}{2}(\sqrt{3}+i)$	1	$\pi/6$
12	$\frac{1}{2}(\sqrt{3}-i)$	11	$-\pi/6$

[A35] The general formula for finding these 12 solutions is; $(1-B^{12})=0 \Leftrightarrow B^{12}=1 \Rightarrow B=e^{\{2j\pi i/S\}}=\cos\left\{\frac{2j\pi}{S}\right\}+i\sin\left\{\frac{2j\pi}{S}\right\}$, where S is the number of observations per year ($S = 12$), and $j = 0,\ldots 11$. If for example $j=\{3,9\}$, we get $B=\pm i$.

[A36] A seasonal series can be described as one with a spectrum having distinct peaks at the seasonal frequencies; $\alpha \equiv 2\pi j/S$, where $j = 1,\ldots,S-1$, and S is the number of observations per year. Here the frequency associated with a particular root is the α in $e^{\alpha i}$, the polar representation of the root; $B=e^{\{2j\pi i/S\}}$, see footnote A1 (Beaulieu & Miron, 1993; Hylleberg, et al., 1990).

The filters in the auxiliary regression (6) with $y_{k,t}$, $k = 1,\dots,12$ are given as;

$$
\begin{aligned}
y_{1t} &= (1+B+B^2+B^3+B^4+B^5+B^6+B^7+B^8+B^9+B^{10}+B^{11})x_t,\\
y_{2t} &= -(1-B+B^2-B^3+B^4-B^5+B^6-B^7+B^8-B^9+B^{10}-B^{11})x_t,\\
y_{3t} &= -(B-B^3+B^5-B^7+B^9-B^{11})x_t,\\
y_{4t} &= -(1-B^2+B^4-B^6+B^8-B^{10})x_t,\\
y_{5t} &= -\tfrac{1}{2}(1+B-2B^2+B^3+B^4-2B^5+B^6+B^7-2B^8+B^9+B^{10}-2B^{11})x_t,\\
y_{6t} &= \tfrac{\sqrt{3}}{2}(1-B+B^3-B^4+B^6-B^7+B^9-B^{10})x_t,\\
y_{7t} &= \tfrac{1}{2}(1-B-2B^2-B^3+B^4+2B^5+B^6-B^7-2B^8-B^9+B^{10}+2B^{11})x_t,\\
y_{8t} &= -\tfrac{\sqrt{3}}{2}(1+B-B^3-B^4+B^6+B^7-B^9-B^{10})x_t,\\
y_{9t} &= -\tfrac{1}{2}(\sqrt{3}-B+B^3-\sqrt{3}B^4+2B^5-\sqrt{3}B^6+B^7-B^9+\sqrt{3}B^{10}-2B^{11})x_t,\\
y_{10t} &= \tfrac{1}{2}(1-\sqrt{3}B+2B^2-\sqrt{3}B^3+B^4-B^6+\sqrt{3}B^7-2B^8+\sqrt{3}B^9-B^{10})x_t,\\
y_{11t} &= \tfrac{1}{2}(\sqrt{3}+B-B^3-\sqrt{3}B^4-2B^5-\sqrt{3}B^6-B^7+B^9+\sqrt{3}B^{10}+2B^{11})x_t,\\
y_{12t} &= -\tfrac{1}{2}(1+\sqrt{3}B+2B^2+\sqrt{3}B^3+B^4-B^6-\sqrt{3}B^7-2B^8-\sqrt{3}B^9-B^{10})x_t.
\end{aligned}
$$

by lagging $y_{k,t}$ once one gets $y_{k,t-1}$.

Appendix 2B: Data Description and Variable Definition

The analysis uses monthly import data from the EU trade statistics, EUROSTAT, from 1981 to 1992 (n=144). The data is extracted from EUROSTAT's COMEXT database Chapter 3 "*Fish and Crustaceans, molluscs and other aquatic invertebrates*". Prior to 1988, fresh salmon was registered as one aggregated product, No. 030103 (EUROSTAT's HS-nomenclature), 'Fresh or chilled Pacific salmon "Oncorhyncus SSP" and Atlantic salmon "Salmo Salar" and Danube salmon "Hucho hucho"'. In 1988 it was dissaggregated into No. 03021200, fresh or chilled salmon and No. 03041013, fresh or chilled fillets of salmon. Hence, to ensure compatibility from 1988 to 1992 these two groups are aggregated. A parallel harmonisation is done for frozen salmon. Prior to 1988 No. 030104, 'frozen Pacific salmon "Oncorhyncus SSP", Atlantic salmon "Salmo Salar" and Danube salmon "Hucho hucho" is used. From 1988 to 1992 No. 03031000, frozen Pacific salmon, No 03032200, frozen Atlantic salmon and No. 03042013 frozen fillets of all salmon are aggregated. Smoked salmon is one aggregated group in EUROSTAT's database, Pacific salmon "Oncorhyncus SSP", Atlantic salmon "Salmo Salar" and Danube salmon "Hucho hucho", smoked, including fillets. Prior to 1988 the nomenclature code for smoked salmon was 030233, and from 1988 to 1992 the code was 03054100. The data was provided by EUROSTAT and was prepared for the present purpose at The Norwegian College of Fishery Science, University of Tromsø, Tromsø, Norway. All values are in ECU, and prices FOB. The prices used are unit prices, i.e. value divided by quantity. All nominal figures were deflated using the corresponding consumer indices using 1985 as the base year. The individual country indices were from IMF's international financial statistics, the EU consumer index was from the OECD statistics.

—Chapter 3—

A Cointegration test for Intertemporal Price Discrimination

3.1. Introduction

There is a growing amount of literature on market delineation using econometric time series techniques to test for price interdependencies.[1] The existing studies focus on two types of market boundaries: geographic market boundaries and product space boundaries. However, in some markets, the time space may be very important. For instance, due to biological constraints, some agricultural products are available only during certain periods. At the same time there may exist year-round producers of close substitutes (e.g. nurseries). The degree of competition in these markets will thus be lower in some periods, and higher in others. In this chapter, market delineation methods are used to test for intertemporal price discrimination and the significance of intertemporal changes in competition.

In a competitive market with no barriers to arbitrage, one would expect the prices of close substitutes to follow some long-run relationship. Competition acts as a disciplinary device forcing prices to marginal cost, and arbitrage will make sure that the law of one price applies. However, if periods exist where the competition in the market is lower due to biological constraints on supply, the price interdependencies may be weaker during these periods. In the extreme case where there exists only one all-year-round producer, its optimal pricing policy will be to set the monopoly price in the low-competition periods.

The most recent studies on market delineation employ cointegration tests as a market delineation methodology (Ardeni, 1989; Goodwin & Schroeder, 1991; Steen, 1994).[2] When cointegration is verified, variables exhibit stable long-run relationships, which means that a spatial price parity equilibrium condition exists. Suppose one has a market consisting of n products, where one product i, is subject to supply constraints that influence the degree of competition. In the low-competition periods, one expects product i 's price to be *less*

[1] See for instance Horowitz, (1980), Stigler, (1985), Benson and Faminow (1990) and Schrank & Roy (1991) for a review of the time series approaches to market delineation.

[2] The rationale for using cointegration tests is discussed more thoroughly in these studies. Both Ardeni and Goodwin & Schroeder use bivariate cointegration tests. Steen uses a multivariate maximum likelihood approach, and also undertakes separate tests to ensure the robustness of the long-run relationship.

interdependent with respect to the other n-1 products' prices. Hence, when testing for cointegration one would expect the prices to exhibit less stable cointegration relations in the low-competition periods. In addition, if the competition effect is significant, one would anticipate that the i'th product may be excluded from the long-run relationship in the low-competition periods.

We show that by dividing the data set in two parts, a low-competition data set and a high-competition data set, undertaking cointegration tests on both data sets and comparing the results from the two regimes, one may test for the significance of intertemporal changes in competition.

To illustrate this the European Union (EU) market for salmon is analysed. The supply of wild-caught fresh Pacific salmon is constrained during certain periods of the year due to regulations and biological conditions, as opposed to farmed salmon, which is supplied throughout the year. Norway supplies more than 70% of all fresh salmon to the EU. In Norway, farm-gate sales of salmon were regulated until 1991. The Fish Farmers' Sales Organisation was authorised by the government to set minimum prices and to authorise exporters. Hence, it has been argued that Norway exercised intertemporal price discrimination in the EU market for fresh salmon in the periods when US and Canada were unable to supply fresh Pacific salmon to the EU (DeVoretz & Salvanes, 1993).

The three main salmon products are fresh, frozen and smoked salmon, representing more than 99% of the salmon market in the EU. There is some evidence that fresh, frozen and smoked salmon belong to the same market (Steen, 1994). Since both frozen and smoked salmon are year-round products, this suggests that the possibility of exercising intertemporal price discrimination in the fresh market segment is limited. Hence, this chapter investigates the same picture, but from a different angle, focusing on the seasonality in supply and its impact on competition.

A monthly data set from 1981 to 1992 is utilised. The data set is divided into low- and high-competition periods, and cointegration tests are undertaken. If the degree of competition is important in determining the price of fresh salmon, and if Norway actually exercises some intertemporal price discrimination, then the low-competition data should systematically reveal a less stable cointegration relationship than the high-competition data. Further, if the competition effect is significant, one should find that fresh salmon may be excluded from the long-run relationship. We use the multivariate cointegration methodology developed by Johansen (1988; 1991) and Johansen & Juselius (1990).

The empirical results are interesting. The analysis concludes with less stable cointegration relationships in the low-competition periods than in the high-competition periods. However, it is not possible to conclude that fresh salmon is excluded from the long-run relationship. Hence, intertemporal changes in competition matter, but not to the extent that Norway is free to set the price for fresh salmon independently of the prices of frozen and smoked salmon even in the low-competition periods. Or to be more precise, intertemoral changes in supply affect the level of competition, but the substitution determined price bindings are to strong to allow intertemporal price discrimination in this market.

The chapter is organised as follows. In the next section industry characteristics are presented. Section 3 presents the methodology; multivariate cointegration tests. Section 4 presents the empirical cointegration results, and concluding comments are presented in the final section.

3.2. Industry Characteristics

Japan, the US and the EU are the world's most important salmon markets. Norway is the biggest producer of farmed salmon, exporting more than 70% of its production of salmon to the EU from 1988 to 1992.[3] The US and Canada are the largest suppliers of wild-caught Pacific salmon to the EU, while Norway, the US and Canada are the three main suppliers of frozen salmon. Norway has been the main supplier of fresh salmon throughout the period, with an average market share of 72%. Norwegian farm-gate sales of salmon were closely regulated until 1991. The Fish Farmers' Sales Organisation was authorised by the government to set minimum prices, promote Norwegian

[3]In all cases where no particular data source is referred to, the numbers presented are based on data from the EU trade statistics; EUROSTAT. The data set is presented in the appendix.

salmon world-wide and collect market information. A government license was required for export until July 1991, and though the number of exporters was fairly large, the biggest 10 accounted for 59% of total salmon export in 1989-90 (Bjørndal & Salvanes, 1992). Hence, due to the structure and the regulation of this industry, several studies have argued that it is reasonable to treat Norway as a *unit* (Herrmann & Lin, 1988a, 1988b; DeVoretz & Salvanes, 1993).

The supply of wild-caught fresh Pacific salmon is constrained during certain periods of the year due to regulation and biological conditions. Farmed salmon, on the other hand, is supplied throughout the year. Thus, it has been argued that Norway as the dominant supplier could exercise seasonal monopoly power and intertemporal price discrimination in the market for fresh salmon in the periods when US and Canada were unable to supply fresh Pacific salmon to the EU (DeVoretz & Salvanes, 1993).

Production of both wild-caught and farmed salmon increased considerably from 1980 to 1990. The increase in farmed salmon was considerably higher than the increase in wild-caught salmon, but wild salmon still dominates world production.[4] There are several species of wild salmon. However, only *chinook* and *coho* are similar in quality with Atlantic farmed salmon (i.e. flesh texture etc.). These two species are also the only Pacific species that are farmed. One of the reasons for the quality differences is the harvesting method; both *chinook* and *coho* are usually caught with a trolling line. The other species are usually caught with trollnet and driftnet (nets can leave unsightly burn marks on the skin). S*ockeye* is also promoted as a substitute to the Atlantic salmon (Bjørndal & Salvanes, 1992). [5] Most of the *sockeye* is exported to Japan. *Sockeye* was earlier mainly canned.[6]

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[4] In 1980 farmed salmon represented 1% of the total quantity of salmon (wild-stock landings and farmed salmon); in 1990 farmed salmon represented 27%. The total quantity of salmon produced increased by 89% during this period (Bjørndal & Salvanes, 1992). Farmed salmon quantity increased sixtyfold from 1980 to 1990, and landings of wild-caught salmon were doubled in the same period.

[5] In the period from 1980 to 1985 *Chinook*, *Coho* and *Sockeye* represented on average 3.3, 5.6 and 21.4% of wild-caught salmon landings, respectively (Bjørndal, 1990).

[6] The other two important wild species, *Chum* and *Pink* , are mainly used as input in the canning and smoked salmon industry. In the period from 1980 to 1985 these two accounted for 69.2% of the wild-caught salmon landings (Bjørndal, 1990).

Chinnok and *coho* are actually landed all year but only in very small quantities outside the main seasons (Holmefjord, 1988). The definition of the competition periods is based on the harvest seasons, and the monthly distribution of North-American supply. The largest salmon runs, and therefore the most substantial harvest, take place in the fall. To define the length of the high-competition period with more accuracy, the monthly averages of fresh Pacific salmon exported to the EU from the US and Canada during the period from 1981 to 1992 are investigated. Figure 1 illustrates this average distribution.

A clear pattern is visible. Exports for January and the last five months of the year are all substantially higher than the rest of the year. When comparing each month's average to the year's average, the period from August to December is above, and January is approximately at the average.[7] When investigating the supply pattern for the US and Canada individually, the picture is the same. The late fall peak, coincides with the period for the largest salmon runs. As for January and the last five months' share of yearly supply (the high-competition period), 83.8% of the North American salmon (as calculated as the 12 year average) is supplied to the EU during this period. The individual supply figures for the high-competition periods for the US and Canada are 83.6 and 84.6, respectively. Also, demand shifts according to seasons, but this seasonality is a lot less distinct than the North American supply seasonality. Typically one finds two demand peaks for fresh salmon, one in summer (June) and one in the Christmas season. The average share of consumption of all fresh salmon in the EU in the high competition periods from 1981 to 1992 is 55%, which is considerably less than the North American supplies' share of 83.8%. Thus, the seasonality in demand does not explain the asymmetries in the North American supply. Hence, the period from August through January is chosen as the high-competition period, and February through July as the low-competition period. Monthly data for the period January 1981 to December 1992 are used (n=144). Thus, each of the two data sets contain 72 observations. The monthly averages and the competition status are given in Table 1.

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[7] The reason that January is so high in these data is probably that there is a certain registration delay in the database. The database used is the EU's trade statistics; EUROSTAT.

Figure 1

North American monthly export distribution of fresh Pacific salmon to the EU, 1981 to 1992 (in tonnes).

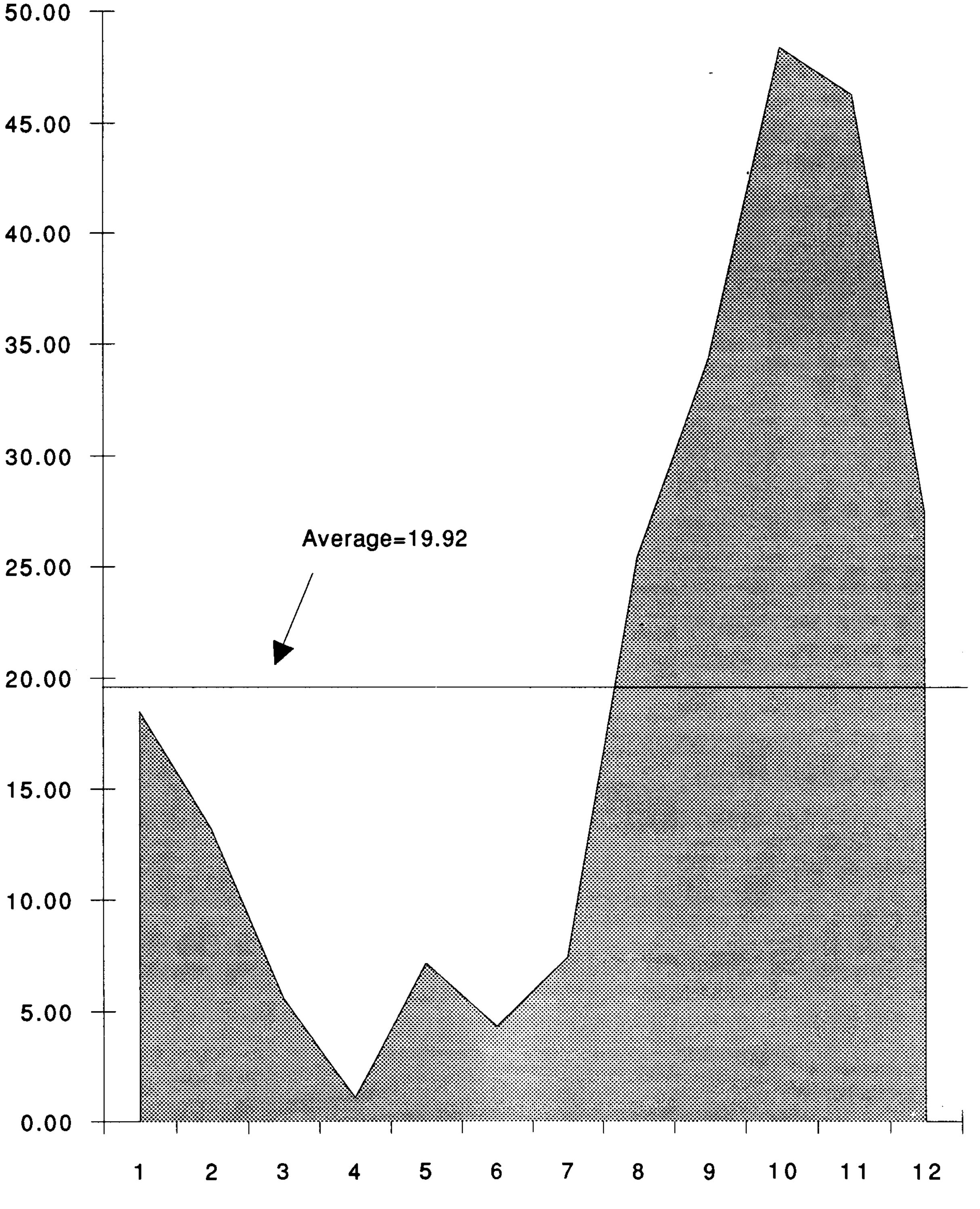

Table 1

Monthly averages of fresh Pacific salmon exported to the EU from the US and Canada, 1981 to 1992 (in 1000 kilo).

	Canada	US	Canada & US	Competition Status
January	3.50	15.00	18.50	High
February	1.25	11.92	13.17	Low
March	0.17	5.42	5.58	Low
April	0.25	0.83	1.08	Low
May	0.08	7.08	7.17	Low
June	1.17	3.17	4.33	Low
July	2.83	4.58	7.42	Low
August	5.58	19.83	25.42	High
September	5.00	29.33	34.33	High
October	10.58	37.75	48.33	High
November	2.50	43.75	46.25	High
December	4.50	23.00	27.50	High
Monthly Average	3.12	16.81	19.92	

Even though the US and Canada have relatively small market shares in the EU, their production (capacity) may discipline the other suppliers, and may thus be important to the level of competition in the EU in the high-competition period. If the price of fresh salmon in Europe reaches a sufficiently high level, then these countries have the capacity to supply large amounts of high quality Pacific salmon.[8] During the period from 1983 to 1987, total yearly EU consumption of fresh salmon amounted to 41% of total yearly landings of *coho* and *chinook* on average. Accounting for the supply pattern, where most of the salmon is caught during the main seasons, the US and Canada could have supplied the entire EU market for fresh salmon in this period in all of these five years.[9] However, outside the main seasons, the North American capacity is severely limited.

[8]US and Canada have a considerable export trade in salmon. Most of their export of fresh salmon goes to Japan. In 1986, 86% of the value of the US's export of fresh and frozen salmon came from export to Japan (Wessells & Wilen, 1993). However, if the price level in Europe increased sufficiently, the industry would find it profitable to increase the supplies to Europe.

[9]Even though a substantial quantity of *Chinnok* and *Coho* is consumed domestically, this argument applies during the salmon run period.

Empirical studies have concluded with varying degrees of substitutability between fresh and frozen salmon. Moreover, fresh and frozen salmon are used as input in the salmon smoking industry (Herrmann & Lin, 1988b; Bjørndal, *et al*, 1992; DeVoretz & Salvanes, 1993). Multivariate cointegration tests applied to the aggregated EU salmon market and to the French salmon market provide some evidence that fresh, frozen and smoked salmon belong to the same market (Steen, 1994). However, tests for spatial price discrimination in the EU are more ambiguous, since they suggest two different geographic markets for frozen salmon in the EU: one market in France, and the rest of the EU as an aggregate market. France has a large salmon processing industry, and then in particular a considerable smoked salmon industry. Of total quantity smoked salmon consumed in France, between 70 and 80% is domestically produced (Monfort, 1992). This gives a different market structure in France, and provides an explanation of these findings (Steen, 1994). The market for fresh salmon is found to be more integrated, i.e., one EU market for fresh salmon. Hence, cointegration tests are undertaken for three areas: the EU, France, and an aggregate market with Belgium, Luxembourg, Holland, Germany, UK and Denmark.[10]

3.3. Methodology

Stigler (1969, p. 85) defined a market as: "*The area within which the price of a commodity tends to uniformity, allowance being made for transportation costs*". This arbitrage-based definition has motivated a growing amount of literature on market delineation using econometric time series techniques to test for price interdependencies. Compared to earlier econometric approaches, the cointegration methodology captures the long-run properties of the variables also when dealing with non-stationary data. The idea of cointegration is that even if two or more variables in themselves are not stationary in the levels, linear combinations (so-called cointegration vectors)

[10]In the period from 1981 to 1992 France accounted for 37.4 and 52.3% of the EC market for fresh and frozen salmon. The corresponding figures for the aggregate market are 51.7% (fresh) and 41% frozen).

which are stationary may exist(Engle & Granger, 1987). If cointegration is verified, variables exhibit a stable long-run relationship, which in this context implies that *a price parity equilibrium condition* exists. Prices may drift apart from one another in the short-run due to random shocks, sticky prices, contracts etc.; but in the long-run, economic equilibrium processes force the prices back to their long-run equilibrium paths (Engle & Granger, 1991). Cointegration vectors could be thought of as representing constraints that an economic system imposes on the movements of the variables in the system in the long-run. Hence, the more cointegration vectors there are, the more stable the system is. Therefore it is desirable for an economic system to be stable in as many directions as possible, all other things being equal (Dickey, *et al*, 1991). Johansen (1988; 1991) and Johansen & Juselius (1990) have developed a multivariate method that provides a matrix with all possible distinct cointegrating vectors based on all variables investigated. They also provide test statistics for determining the number of significant cointegration vectors.

3.3.1. Cointegration and Integration Order

Consider two series of economic variables, x_t and y_t. Each series by itself is nonstationary and is required to be differenced once to produce a stationary series. However, a linear combination of the two series,

(1) $$y_t - \psi x_t = \varepsilon_t$$

may produce a residual series ε_t which is stationary. In this case, the series x_t and y_t are said to be cointegrated. Or more precisely, the series are said to be *cointegrated of order (1,1)* with the vector $[1, -\psi]$ called the *cointegration vector.* A straightforward generalisation for the case of *n* variables is the following. If x_t denotes an $n \times 1$ vector of series $x_{1t}, x_{2t}, \ldots, x_{nt}$ and each of them is *I(d)* and there exists an $n \times 1$ vector β such that $\mathbf{x}_t' \cdot \beta \sim I(d-b)$ (where $d \geq b \geq 0$), then $\mathbf{x}_t' \cdot \beta$ is cointegrated of order d,b, (Engle & Granger, 1987).

Before testing for cointegration one has to verify the variables' integration order. The most common test for integration is the test for a unit root developed by Dickey and Fuller (1979; 1981). The development in a series x_t is assumed to be described by an autoregressive process AR(1);

(2) $$x_t = \rho \cdot x_{t-1} + \varepsilon_t,$$

where $\varepsilon_t \sim iid(0,\sigma)$. When $\rho = 1$, this process is nonstationary, i.e. it has a unit root. However, if $|\rho| < 1$, the series is stationary in the levels. Thus, the null hypothesis of a unit root tested for in the Dickey Fuller test is $\rho = 1$. To capture autocorrelated omitted variables (which would otherwise by default appear in the necessarily autocorrelated error term) it has been common practice to include lagged first differenced dependent variables on the RHS of (2);

(3) $$x_t = \rho \cdot x_{t-1} + \sum_{j=1}^{k} \gamma_j \Delta x_{t-j} + \varepsilon_t.$$

This test is commonly referred to as the Augmented Dickey-Fuller (ADF) test. Critical values for the test statistics may be found in Fuller (1976). The test is amenable to the case where the alternative includes a time trend and a constant term. However, the distribution of the critical values changes with the inclusion of such nuisance parameters. To determine the lag length, k, one starts with a sufficiently high k, and tests with decreasing k's until the last lag is found significant (Schwert, 1989; Campbell & Perron, 1991).

In this market, seasonal variations in demand are important (Bjørndal, Salvanes & Andreassen, 1992; Herrmann & Lin, 1988b). Deterministic seasonality is removed by *a priori* regression of the series in levels on seasonal dummies and a constant term; the residuals for this regression are then treated in the subsequent analysis as if they were the true x-series (Dickey, Bell & Miller, 1986; Osborne *et al*, 1988). This procedure also removes possible deterministic jumps that one may have imposed on the series by extracting only a six-month-long window every year.

Equation (3) is estimated separately for fresh, frozen and smoked salmon for the three geographical areas for the high-competition and the low-competition groups, using the described procedure.[11] The results are tabulated in Table 2. [12]

Table 2

Augmented Dickey-Fuller tests for integration order for prices on fresh, frozen and smoked salmon in the EU, 1981 to 1992, High-competition and Low-competition periods (n=72).[1]

	EU				France				Aggregate Market			
	$I(0)$	Lag	$I(1)$	Lag	$I(0)$	Lag	$I(1)$	Lag	$I(0)$	Lag	$I(1)$	Lag
						High-competition						
Fresh	-0.720	3	-6.658*	2	-0.816	6	-4.246*	5	-0.814	7	-4.060*	6
Frozen	-1.306	5	-3.042**	4	-0.475	12	-3.425*	11	-0.929	10	-3.167**	9
Smoked	-0.594	4	-6.595*	3	-1.505	3	-7.070*	2	0.058	5	-5.741*	4
						Low-competition						
Fresh	-0.469	8	-3.545*	7	-0.227	9	-4.402*	8	-0.378	8	-3.708*	7
Frozen	-0.205	10	-4.295*	9	0.426	10	-3.812*	9	-0.784	10	-3.912*	9
Smoked	-0.701	7	-2.860***	6	-2.356	2	-10.144*	1	-0.026	2	-11.457*	1

*/significance at a 2.5% level, **/significance at a 5% level, ***/significance at a 10% level.
[1]/Critical values are from Fuller, (p. 373, 1976).

The null hypothesis of a unit root in the levels are accepted for all the 18 series. When testing the first differences, the null hypothesis is rejected in 15 cases at the 0.025 level, in 2 at the 0.05 level and in one (EU, low-competition, smoked) at a 0.10 level. Hence, all 18 series are found to be stationary in the first differences—the series are $I(1)$. The test statistics were in all cases stable for varying lag lengths. Thus, the series could all be used as variables in the cointegration analysis, where one searches for linear combinations of $I(1)$ variables that are $I(0)$.

[11]A constant term is included in (3) but the time trend is omitted, something which is also concluded when testing for cointegration in section 4 (see footnote 16).

[12]In all the tests the Ljung-Box Q-statistics (Ljung & Box, 1979) show no autocorrelation of higher order.

3.3.2. The Multivariate Cointegration Methodology

Johansen (1988) shows how to find the number of cointegration vectors in a given set of variables. The methodology is later expanded to also account for factors such as deterministic seasonality and time trends (Johansen and Juselius, 1990 and Johansen, 1991). Even though the methodology is quite complex, the intuition behind it is more straightforward. To find the possible stationary linear combinations, the cointegration vectors, the data is divided into two groups, the variables in levels, and their first differences. Under the assumption of $I(1)$ processes, the differenced data are stationary. Using the technique of canonical correlation from the theory of multivariate analysis, the linear combinations of the data in levels which are highly correlated with the differences are found. If the correlation is sufficiently high, it follows that these linear combinations are stationary, and so are the cointegration vectors.

More formally, the vector of N variables $\mathbf{x}_t$ is assumed to be generated by an unrestricted vector autoregression (VAR) in the levels of the variables,

$$(4) \qquad \mathbf{x}_t = \Pi_1 \mathbf{x}_{t-1} + \ldots + \Pi_k \mathbf{x}_{t-k} + \Phi D_t + \mu + \varepsilon_t,$$

where each of the Π_i is an $(N \times N)$ matrix of parameters, D_t are seasonal dummies orthogonal to the constant term μ and $\varepsilon_t \sim niid(0, \Omega)$. The VAR-system of equations in (4) written in error correction form (ECM) is

$$(5) \qquad \Delta \mathbf{x}_t = \sum_{i=1}^{k-1} \Gamma_i \Delta \mathbf{x}_{t-i} + \Pi_K \mathbf{x}_{t-k} + \Phi D_t + \mu + \varepsilon_t$$

with $\Gamma_i = -I + \Pi_1 + \ldots + \Pi_i$, $i = 1, \ldots, k-1$. Hence, Π_K is the long-run 'level solution' to (4). If $\mathbf{x}_t$ is a vector of $I(1)$ variables, the left-hand side and the first $(k-1)$ elements of (5) are $I(0)$, and the last element of (5) is a linear combination of $I(1)$ variables. Given the assumption on the error term, this last element must clearly also be $I(0)$; $\Pi_K x_{t-k} \sim I(0)$, hence either $\mathbf{x}_t$ 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 $\mathbf{x}_t$ are stationary. If r=N, the variables in levels are stationary; if r=0 so that Π_K=0, none of the linear combinations are stationary. When 0< r<N , r cointegration vectors, or r stationary linear combinations of $\mathbf{x}_t$ exist . In this case one can factorize Π_K; $-\Pi_K = \alpha\beta'$, where both β and α are $(N \times r)$ matrices, and β contains the cointegration vectors (the error correcting mechanism in the system) and α the adjustment parameters.

Johansen and Juselius show that after undertaking appropriate factorizing and by solving an eigenvalue problem it is possible to test for the number of significant vectors using two different tests, the 'trace' test and the 'maximal eigenvalue' test. The trace test (η_r) is a likelihood ratio test for *at most r cointegrating vectors;* $\eta_r = -T\sum_{i=r+1}^{N}\ln\left(1-\hat{\lambda}_i\right)$, where T is number of observations and the $\hat{\lambda}_i$ are the eigenvalues that solve the eigenvalue problem. The maximal eigenvalue test (ξ_r), is a test of *the relevance of column* r+1 *in* β; $\xi_r = -T\ln\left(1-\hat{\lambda}_{r+1}\right)$.

Price series which in general have independent processes could be weakly cointegrated if they are exposed to substantial common cost or demand shocks, rather than the economic activities relevant to market delineation such as substitution and arbitrage. Steen (1994) shows the importance of undertaking exclusion tests on the long-run parameters in $\hat{\beta}$ to ensure the robustness of the cointegration relationship. Hence, to conclude that products belong to the same market, it is also required that all the price series contribute significantly to the long-run relationship. Here one is interested in how changes in the degree of competition affect fresh salmon's interaction with frozen and smoked salmon. Thus, tests for the significance of the fresh salmon price series in the cointegrating relations are undertaken. Given a cointegration relationship, exclusion tests are imposed as null restrictions on the long-run parameter for fresh salmon in $\hat{\beta}$. The null hypothesis is then; 'H_0:$\hat{\beta}_{fresh} = 0$; *the market consists of smoked and frozen salmon only*' against the alternative; '*one common market exists for all three products*'. If one rejects the null hypothesis, fresh salmon significantly contributes to the cointegrating relation, implying that fresh salmon is a part of the market. Note that if there is more than one cointegration vector a joint exclusion test requiring all corresponding parameters across the vectors to the be zero has to be performed, e.g. with two cointegration vectors, the null hypothesis would be; $H_0:\hat{\beta}_{1,fresh}=\hat{\beta}_{2,fresh}=0$. If changes in the competition level are important one will expect to accept the null more frequently in the low-competition periods than in the high-competition periods. [13]

To take care of possible linear trends in the variables, the constant term μ serves a dual function. When the series are believed to contain a linear trend the constant term in (5) is partitioned to include also a time trend. The linear trends are treated as common, i.e. they cancel in the cointegration relations. In a model without time trend the constant term will only appear as part of the cointegration vectors, i.e. the ECM representation contains any constant within the term $\Pi_K \mathbf{x}_{t-k}$ only. The significance of a linear time trend is tested for using an ordinary likelihood test (Johansen & Juselius, 1990; Hamilton, 1994).

A problem when analysing price series is the existence of possible underlying common factors. If these dominate the individual variation in the series, one could obtain spurious results by accepting interdependencies erroneously even when utilising deflated price series. In the present case such a common factor could be a general upward movement in the price levels. Hence, in addition to deflating the price series, the consumer price index is included in the VAR system as a predetermined variable that is not allowed to enter the cointegration space. Thus, it is treated as a common factor which cancels in the cointegration relations.[14]

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[13]The null restrictions on the parameters in $\hat{\beta}$ are tested using a likelihood ratio test. First one estimates the unrestricted model and solves the eigenvalue problem, then one estimates the model with the restriction(s) imposed and calculates the restricted eigenvalues $\hat{\lambda}_1^* > ... > \hat{\lambda}_r^*$. Finally, one calculates the test statistics given by: $LR^*[r(N-s)] = T\sum_{i=1}^{r}\ln\{1-\hat{\lambda}_i^*/1-\hat{\lambda}_i\}$. The test statistic has an asymptotic chi-square distribution with $r(N-s)$ degrees of freedom, where s is the number of independent cointegration parameters in the restricted model.

[14]The results were obtained using a RATS program written by Katarina Juselius (Juselius, 1991), which was kindly made available by Gunnar Bårdsen.

3.4. Empirical Results

Three geographical areas, the EU, France and the aggregate market with Belgium, Luxembourg, Holland, Germany, UK and Denmark are analysed. With one high-competition and one low-competition data set for each area, six multivariate cointegration tests have to be undertaken. The matrix of variables in (5), $\mathbf{x}_t$, consists of the three deflated price series, fresh, frozen and smoked salmon in logarithms, i.e. $\mathbf{x}_t = \left[x_{t,FH}, x_{t,FZ}, x_{t,SM}\right]$ (see appendix for precise variable definitions). The same *a priori* procedure as in section 3 is used to remove deterministic seasonality. Thus, the seasonal dummy variables in (5) are excluded. The monthly consumer price index is included in (5) as a predetermined variable.[15] The maximal eigenvalue test (ξ_r) and the trace test (η_r) based on the VAR system in (5) are presented in Table 3 ($k = 6$).[16]

Cointegration vectors could be thought of as representing constraints that an economic system imposes on the movement of the variables in the system in the long run. Hence, the more cointegration vectors there are, the more stable the system is. Therefore it is desirable for an economic system to be stable in as many directions as possible, all other things being equal (Dickey, *et al*, 1991). In the EU, the test concludes *two* cointegration vectors at the 2.5% level in the high-competition period, but only *one* in the low-competition period. In France, the test statistics for the possible existence of two cointegration vectors are significantly lower in the low-competition period than in the high-competition period. In the aggregate market, the pattern is even more distinct. Here the test provides evidence for one cointegration vector at the 10% level in the high-competition period, but none in the low-competition period.[17] This last result means

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[15]The consumer price index used to represent the predetermined common factor and to deflate the price series for the aggregated group is a Laspeyres index based on the six countries' individual consumer price indices weighted with the value of salmon sold in each country (1985:01=100). Belgium and Luxembourg are included as an aggregate in EUROSTAT's statistics. The Belgian consumer price index is used to represent these two countries. All indices are from the IMF's International Financial Statistics, the EU consumer price index is from OECD (1985=100). The Laspeyres indices are computed using the SHAZAM econometric packages (White, 1978).

[16]The tests are done both with a linear trend imposed and without. The restriction of no trend is accepted in all models significantly. Hence, the results presented here are based on VAR-models with no linear trend and an intercept term in each cointegration vector.

[17]When investigating the correlation coefficients for these variables, one observes the same pattern as when using the cointegration tests. The correlation coefficients are always lower in the low-competition periods.

Table 3

Multivariate cointegration tests for fresh, frozen and smoked salmon based on the VAR system in (5), critical values η_r and ξ_r.

	EU		France		Aggregate Market	
	ξ_r	η_r	ξ_r	η_r	ξ_r	η_r
			High Competition			
1 coint. vec r=0	21.03***	44.28*	22.46**	39.44*	18.79†	34.75***
2 coint. vec r=1	15.06***	23.25*	10.84	16.98	11.88	15.95
3 coint. vec r=2	8.19***	8.19***	6.14	6.14	4.08	4.08
			Low Competition			
1 coint. vec r=0	23.53**	38.08*	26.56*	35.68**	17.85	29.20
2 coint. vec r=1	10.27	14.55	5.54	9.12	6.69	11.35
3 coint. vec r=2	4.28	4.28	3.58	3.58	4.66	4.66

*/ Significant at a 2.5% level, **/ significant at a 5% level, ***/ significant at a 10% level, the critical values are from Osterwald-Lenum, (1992).

† The critical value for one cointegration vector in the maximum eigenvalue test at a 90% level, is 19.77. Hence, the test statistics; ξ_r=18.79, is nearly significant at a 90% level.

that the products are not in the same market in the low-competition period in this aggregate market: no price parity equilibrium exists. Hence, the six cointegration tests show a systematic pattern by concluding that there is a less stable cointegration relationship in the low competition period than in the high-competition period. However, for five out of the six cointegration tests at least one significant cointegration vector is found, indicating quite strong price interdependencies in both competition periods.

The next step is to test for the significance of the fresh salmon price series in these cointegration relationships. This is done by implementing null-restrictions on the long-run parameters in $\hat{\beta}$ for fresh salmon, and employing exclusion tests (for estimation details see Johansen & Juselius, 1990 and Hamilton, 1994). The likelihood statistics are shown in Table 4.

Table 4

Exclusion tests for fresh salmon.

	EU	France	Aggregate Market
		High Competition	
$H_0:\beta_{j,fresh}=0$	7.71*	8.31*	5.65*
		Low Competition	
$H_0:\beta_{j,fresh}=0$	6.73*	10.05*	—

*/significant at a 2.5% level, for France, the aggregate market and the EU in the low-competition period the tests are based on one cointegration vector; $r(N-s)=1(4-3)=1$, for the EU in the high competition-period the test is based on two cointegration vectors; $r(N-s)=2(4-3)=2$.

The null hypothesis of exclusion of fresh salmon is rejected in all of the five tests at a 2.5% significance level. There is no pattern to indicate that the null hypothesis is rejected more easily in the high-competition period. Hence, the exclusion tests indicate that Norway is not free to set price independently of the prices of frozen and smoked salmon even in the low-competition periods.

However, the exclusion tests undertaken are quite strong. By testing for $\beta_{j,fresh}=0$, one restricts the long-run parameters in the VAR system in (5) to zero in both the equation for frozen and the equation for smoked salmon simultaneously, i.e. one jointly requires the long-run relationship between fresh and frozen salmon and the relationship between fresh and smoked salmon to be zero. For instance, the price interdependencies between fresh and smoked may be significantly weaker in the low-competition periods, but sufficiently strong interdependencies between fresh and frozen salmon make our exclusion tests reject the 'joint' null hypothesis. An analogue interpretation is the difference of using a joint F-test as opposed to two separate t-tests. To investigate this, bivariate cointegration tests between fresh and frozen salmon, and between fresh and smoked salmon, are undertaken. If these relationships are of different strengths, the bivariate tests should uncover these differences. The results of the bivariate tests are presented in

Tables 5 and 6.

Table 5

Bivariate cointegration tests for fresh and frozen salmon based on the VAR system in (5), critical values η_r and ξ_r.

	EU		France		Aggregate Market	
	ξ_r	η_r	ξ_r	η_r	ξ_r	η_r
			High Competition			
1 coint. vec r=0	14.99***	23.10*	12.90	18.39***	16.57**	26.10*
2 coint. vec r=1	8.10***	8.10***	5.49	5.49	9.53**	9.53**
			Low Competition			
1 coint. vec r=0	12.29	14.92	7.37	10.37	14.73***	20.72**
2 coint. vec r=1	2.63	2.63	3.00	3.00	5.99	5.99

*/ Significant at a 2.5% level, **/ significant at a 5% level, ***/ significant at a 10% level, the critical values are from Osterwald-Lenum, (1992).

Table 6

Bivariate cointegration tests for fresh and smoked salmon based on the VAR system in (5), critical values η_r and ξ_r.

	EU		France		Aggregate Market	
	ξ_r	η_r	ξ_r	η_r	ξ_r	η_r
			High Competition			
1 coint. vec r=0	20.01*	28.12*	20.54*	27.49*	10.21	13.47
2 coint. vec r=1	8.11***	8.11***	6.96	6.96	3.26	3.26
			Low Competition			
1 coint. vec r=0	8.45	13.03	13.91***	16.85	7.73	11.53
2 coint. vec r=1	4.58	4.58	2.95	2.95	3.80	3.80

*/ Significant at a 2.5% level, **/ significant at a 5% level, ***/ significant at a 10% level, the critical values are from Osterwald-Lenum, (1992).

For the EU, the tests indicate one significant cointegration vector in the high-competition period for the fresh-frozen salmon relation and the fresh-smoked salmon relation, but none in the low-competition period. This corresponds to the multivariate result where one vector disappeared in the low-competition period, leaving more room for price discrimination in the low-competition period. In France, the tests indicate a less distinct pattern when testing for the fresh-frozen salmon relation. However, when testing for the fresh-smoked salmon relation one moves from one very clear cointegration vector at the 2.5% level in the high-competition period, to the situation where one can keep the vector only at a 10% level in the low-competition period. The results for the aggregate market are even more ambiguous, suggesting no long-run relationship between fresh and smoked salmon in any of the competition periods, but a clear relationship between fresh and frozen salmon in both periods. This may explain why the multivariate test concluded with no multivariate cointegration in the low-competition period in this market.

Hence, the bivariate test results give no clear indication of which of the relationships, fresh-frozen salmon or fresh-smoked salmon, is most affected by the changes in the degree of competition. In France, the relationship between fresh and smoked salmon seems to be more affected than the relationship between fresh and frozen salmon. However, in the EU and the aggregate market there are no clear differences.

The results using bivariate methods are overall more ambiguous due to the omitted effect from the third salmon product (e.g. when testing for price interdependencies between fresh and frozen salmon, the information captured by the smoked salmon price series is omitted). This is expected, because bivariate methods by definition ignore possible linkages which may operate through another market within the system. Hence, the multivariate results are more credible and should be given more weight when making conclusions. However, even though more ambiguous, the same systematic pattern of a less stable cointegration relationship in the low-competition periods can be traced in the bivariate tests too. Thus, the bivariate results support the multivariate findings.

Both the multivariate and the bivariate tests exhibit the same pattern across the three geographic areas, indicating that the different industry structure in France has no significant effect for the intertemporal changes in competition level.

The summary of the multivariate and the bivariate results show that they support the hypothesis which stated that a reduction in the degree of competition affects the stability of the cointegration relations negatively, thus suggesting a lower interdependence of prices in the low-competition periods. However, the multivariate tests conclude that cointegration exists in both the high-competition and the low-competition periods, and the exclusion tests do not allow one to exclude fresh salmon. Hence, the interdependencies between fresh, frozen and smoked salmon are too strong to allow prices of fresh salmon to move independently. Or more precisely, intertemoral changes in supply affect the level of competition, but the demand side determined price bindings are too strong to allow intertemporal price discrimination in this market. In conclusion, intertemporal changes in competition matter, but not to the extent that Norway is free to set the price of fresh salmon independently of the prices of frozen and smoked salmon even in the low-competition periods. This result corresponds to the results found in Steen (1994), where fresh, frozen and smoked salmon were found to belong to the same market. The present analysis also accounts for intertemporal changes in competition. Thus, the results provided here strengthen the basis for concluding that there is an integrated market.

Using data from 1983 to 1988, DeVoretz and Salvanes (1993) argue that Norway may have had seasonal monopoly power and thus may have exercised intertemporal price discrimination in the market for fresh salmon in the periods where wild caught salmon was unavailable. The analysis here concludes that Norway is constrained by the prices of frozen and smoked salmon also in the these periods (the low-competition periods), thus countering theirt argument.

3.5. Conclusions

Using tests for market delineation, this chapter focuses on the importance of intertemporal changes in the degree of competition. In a competitive market with no barriers to arbitrage, one would expect the prices of close substitutes to follow some long-run relationship. Competition acts as a disciplinary device forcing prices to marginal cost, and arbitrage forces prices of close substitutes sold in the same market to uniformity. However, if there are periods in which the degree of competition in the market is reduced due to biological constraints on supply, the price interdependencies may be weaker in these periods. We show that by dividing the price series into two parts, a low-competition data set and a high-competition data set, and by undertaking multivariate cointegration tests on both data sets and comparing the results from the two regimes, one may test for the significance of the changes in competition.

The analysis provides some support for the hypothesis that reduced competition negatively affects the stability of the cointegration relations, suggesting a lower interdependence of prices during the low-competition periods. However, the multivariate tests show cointegration in both the high-competition and the low-competition periods, and the exclusion tests do not allow one to exclude fresh salmon from the long-run relationships. Hence, the interdependencies between fresh, frozen and smoked salmon are too strong to allow prices of fresh salmon to move independently. Thus, changes in intertemporal competition matter, but not to the extent that Norway is free to set price on fresh salmon independently of the prices for frozen and smoked salmon even in the low-competition periods. These findings weaken the argument that Norway may have seasonal monopoly power and thus may have exercised intertemporal price discrimination in the market for fresh salmon in the periods inwhich wild-caught salmon was unavailable.

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Appendix 3A: Data Description and Variable Definition

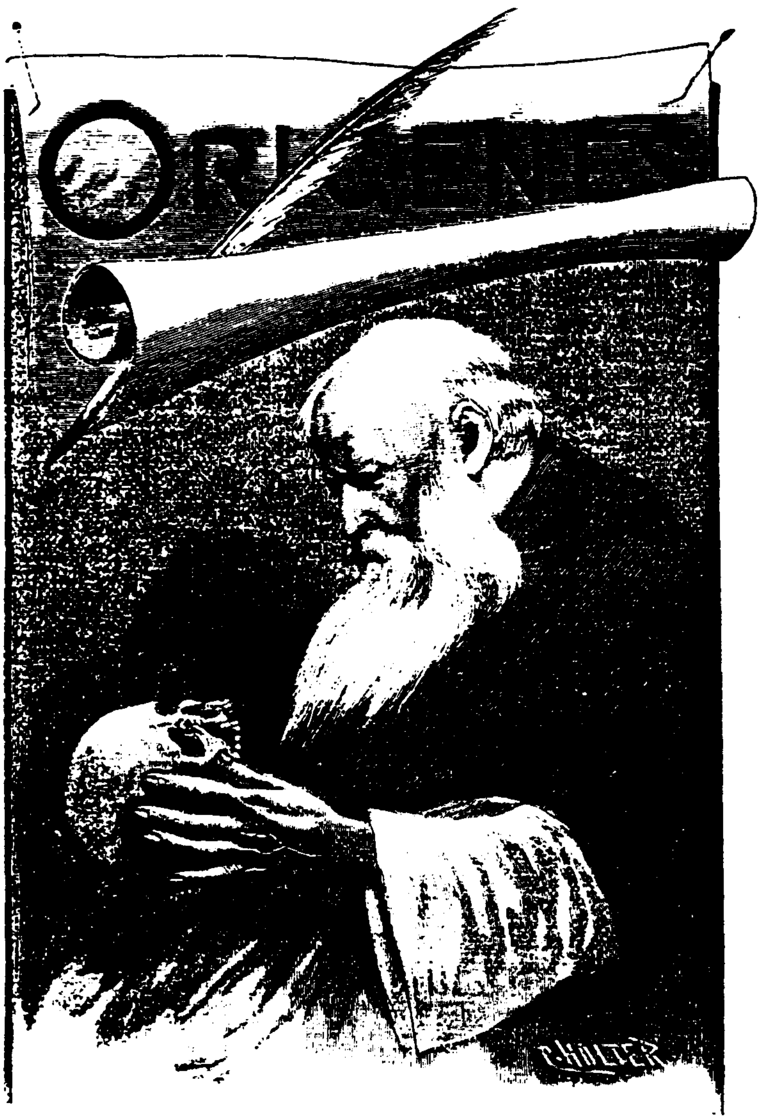
The analysis uses monthly import data from the EU trade statistics, EUROSTAT, from 1981 to 1992 (n=144). The data is extracted from EUROSTAT's COMEXT database Chapter 3 "*Fish and Crustaceans, molluscs and other aquatic invertebrates*". Prior to 1988, fresh salmon was registered as one aggregated product, No. 030103 (EUROSTAT's HS-nomenclature), 'Fresh or chilled Pacific salmon "Oncorhyncus SSP" and Atlantic salmon "Salmo Salar" and Danube salmon "Hucho hucho"'. In 1988 it was dissaggregated into No. 03021200, fresh or chilled salmon and No. 03041013, fresh or chilled fillets of salmon. Hence, to ensure compatibility from 1988 to 1992 these two groups are aggregated. A parallel harmonisation is done for frozen salmon. Prior to 1988 No. 030104, 'frozen Pacific salmon "Oncorhyncus SSP", Atlantic salmon "Salmo Salar" and Danube salmon "Hucho hucho" is used. From 1988 to 1992 No. 03031000, frozen Pacific salmon, No 03032200, frozen Atlantic salmon and No. 03042013 frozen fillets of all salmon are aggregated. Smoked salmon is one aggregated group in EUROSTAT's database, Pacific salmon "Oncorhyncus SSP", Atlantic salmon "Salmo Salar" and Danube salmon "Hucho hucho", smoked, including fillets. Prior to 1988 the nomenclature code for smoked salmon was 030233, and from 1988 to 1992 the code was 03054100. The data was provided by EUROSTAT and was prepared for the present purpose at The Norwegian College of Fishery Science, University of Tromsø, Tromsø, Norway. All values are in ECU, and prices FOB. The prices used are unit prices, i.e. value divided by quantity. All nominal figures were deflated using the corresponding consumer indices using 1985 as the base year. The individual country indices were from IMF's international financial statistics, the EU consumer index was from the OECD statistics.

—Part III—

Market Structure

"Detecting collusion is a lot like searching for skeletons in closets"

(Geroski, 1988, p. 119)



—Chapter 4—

Testing for Market Power using a Dynamic Oligopoly Model: An Application to the EU Market for Salmon

4.1 Introduction

During the last years we have seen a rapid growth in the econometric literature focusing on industry conduct, the existence of market power and various forms of imperfect markets.[1] However, although time series data often is used, the dynamic nature of these industries is often neglected.[2] Bresnahan (1982) and Lau (1982) formulate an oligopoly model that allows for identification of market power using aggregated industry data. By modelling the demand curve and a supply relation their model provides a summary statistic that can be interpreted as the percentage of monopoly marginal revenue perceived in a market.[3] The present chapter proposes a dynamic reformulation of the Bresnahan-Lau (BL) model in an error correcting (ECM) framework.

The most common motivation for using this framework is the statistical importance of accounting for short-run dynamics in the data. Further the framework solves the inference problem when using non-stationary data. The ECM formulation allows for short-run departure from long-run equilibrium in the data. Short-run deviations may be caused by factors such as random shocks, sticky prices, contracts etc., but may also be the result of seasonal shifts in supply and demand. However, by including lagged observations of the endogenous variables, the ECM framework incorporates also dynamic factors as habit formation from the demand side and adjustment costs for the producer. The presence of these factors makes static models inadequate. Hence, the ECM framework provides a solution both to statistical problems generated by short-run dynamics in the data and inclusion of important dynamic factors such as habit formation and adjustment costs.

A crucial feature of the BL model is that if market power is present, the demand function is non-separable in the variables involved in the identification of the market power

[1] Bresnahan (1989) and Geroski (1988) provide a comprehensive review this literature prior to 1988, and Slade (1994) reviews the latest development in this field.

[2] There are some exceptions. Roberts and Samuelson (1988) analysed the US cigarette industry using a dynamic econometric model, estimating intertemporal conjectural variations. Bernstein (1994) uses a dual approach testing for price-cost margins in the Canadian softwood lumber industry. Finally, using state-space models , Karp and Perloff (1989, 1991), Hall (1990), Reynolds (1986) and Slade (1990) incorporate dynamics by modelling two-period or multi-period games empirically.

[3] Several studies utilise this framework empirically (Alexander, 1988; Buschena & Perloff, 1991; Shaffer, 1993; Suominen, 1991).

parameter; Lau's so-called *impossibility theorem.* This property is usually only assumed, and not tested for. In this chapter we propose a test for separability using the multivariate cointegration approach of Johansen and Juselius (Johansen, 1988; Johansen, 1991; Johansen & Juselius, 1990). By undertaking so-called exclusion tests, we show that we can test the separability hypothesis, and thus whether identification of market power is possible.

To illustrate the dynamic specification of the BL model, the European market for salmon is analysed. Since 1980 the international market for salmon has changed considerably due to the development of the farmed salmon industry. This has lead to an increased interest in the market structure of this industry (Bjørndal & Schwindt, 1989; DeVoretz & Salvanes, 1993; Herrmann & Lin, 1988a; 1988b; Singh, 1988; Bjørndal & Salvanes, 1992).[4] In 1981, 6,110 tonnes of fresh salmon was imported in EU, in 1992 this figure had increased to 137,233 tonnes; 22 times higher than the 1981 level. Further, both supply and demand shifts according to seasons. Hence, it is important to utilise a dynamic framework when modelling this market.

Norway is the largest producer of farmed salmon, accounting for more than 56% of the world production of farmed (Atlantic and Pacific) salmon on average during the period from 1986 to 1991. The European Union (EU) is the most important market for Norwegian salmon, and Norway supplies more than 70% of all fresh (including wild-caught) salmon in the EU. In Norway, farm-gate sales of salmon were regulated until 1991. The Fish Farmers' Sales Organisation was authorised by the government to set minimum prices and to authorise exporters in this period. Hence, it has been argued that Norway as a co-ordinated unit was able to set prices in Europe (DeVoretz & Salvanes, 1988; 1993; Herrmann & Lin, 1988a; 1988b). However, none of the previous studies have formulated the market structure explicitly. Hence, utilising the proposed dynamic version of the BL model, we analyse Norway's role in this market.

Multivariate cointegration tests for spatial price discrimination in the EU suggest one integrated geographic market for all fresh salmon (Steen, 1994b). In order to avoid a very high aggregation level, we concentrate on a representative market, France. France is the most

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[4]For a review of this literature see Steen (1994c).

important market for fresh salmon in the EU. In the period from 1980 to 1992, France accounted for 37.4% of the EU market for fresh salmon on average.

The results suggests that the salmon market is competitive in the long-run, but indicate that Norway has some market power in the short-run, a result that is in accordance with conclusions drawn in the literature (Bjørndal & Salvanes, 1992). The demand estimates predict a downward sloping Norwegian residual demand curve. The empirical results are overall reasonable, but due to multicollinearity the estimates show some anomalies. However, the empirical implementation shows that the framework is tractable empirically, and that it provides considerably more information than what the simple static version of the BL model provides. When comparing the static and the dynamic approach, we find the static model inadequate both in terms of statistically and economically predictions.

The chapter is organised as follows. In the next section, industry characteristics are presented. Section 3 presents the Bresnahan-Lau model, and their identification principle. Section 4 presents the dynamic extension of the BL model in the error correcting framework, the separability tests and the empirical specification. Empirical results are presented in section 5, and concluding comments are presented in the final section.

4.2. Industry Characteristics[5]

Norway is the main supplier of fresh salmon in the EU market, with a market share between 69 and 77% in the period from 1981 to 1992. The corresponding figures for Scotland, the second largest supplier, are 8 and 11%.[6] France is the largest importer, representing between 32% to 42% of the EU market alone. Norwegian farm-gate sales of salmon were closely regulated until 1991. The Fish Farmers' Sales Organisation was authorised by the government to set minimum prices, promote Norwegian salmon world-wide and collect market information. A government license was required for export until July 1991, and though the

[5]In all cases where no particular data source is referred to, the source is the EU-trade statistics—EUROSTAT. The data set contains quarterly observations for quantities and values for the period 1981 to 1992 (precise variable definitions are given in Appendix A).

[6]Looking at the seasonal pattern in market shares, the EU market is even more concentrated. If we investigate the monthly market shares for fresh salmon, it is apparent that Norway alone has more than 90% of the market in some months; a pattern that seems to be persistent over the whole sample period (Steen, 1994c).

number of exporters was fairly large, the biggest 10 accounted for 59% of total salmon export in 1989-90 (Bjørndal & Salvanes, 1992). Hence, due to the structure and the regulation of this industry, several studies have argued that it is reasonable to treat Norway as one *unit* (Herrmann & Lin, 1988a, 1988b; DeVoretz & Salvanes, 1993). This has led to claims that Norway has market power in the European salmon market.

In July, 1992 the EU Commission found the Norwegian salmon producers guilty of collusion to set minimum prices in the EU.[7] The Commission's verdict was based on a belief that the Norwegian minimum prices set by the Norwegian Fish Farmers' Sales Organisation (FFSO) "*...set the benchmark for farmed salmon prices (in Europe).*"[8] Or put differently, Norway has been considered as a dominant firm that set the profit maximisation price which the competitive fringe takes as given. However, the existence of year-round substitutes, e.g. North American wild-caught frozen salmon, may discipline a possible strategic behaviour. In particular, if the price of fresh salmon reaches a sufficiently high level, then the US and Canada have the capacity to supply also large amounts of high quality fresh Pacific salmon during the harvest seasons. US and Canada have a considerable export of salmon. Most of their export of fresh salmon goes to Japan. In 1986, 86% of the value of the US's export of fresh and frozen salmon came from export to Japan (Wessells & Wilen, 1993). However, if the price level in Europe increased sufficiently, the industry would find it profitable to increase supplies to Europe. Hence, the question of market power is not straightforward to answer. Furthermore, the seasonal structure of this market suggests existence of dynamic strategic behaviour.

There has been a rapid and large increase in this market. Even though the demand curve has shifted outwards, the substantial increase in supply has lead to a decrease in the fresh salmon price over the analysed period. The quantity of fresh salmon imported from Norway to France and the fresh salmon price are drawn in Figure 1.

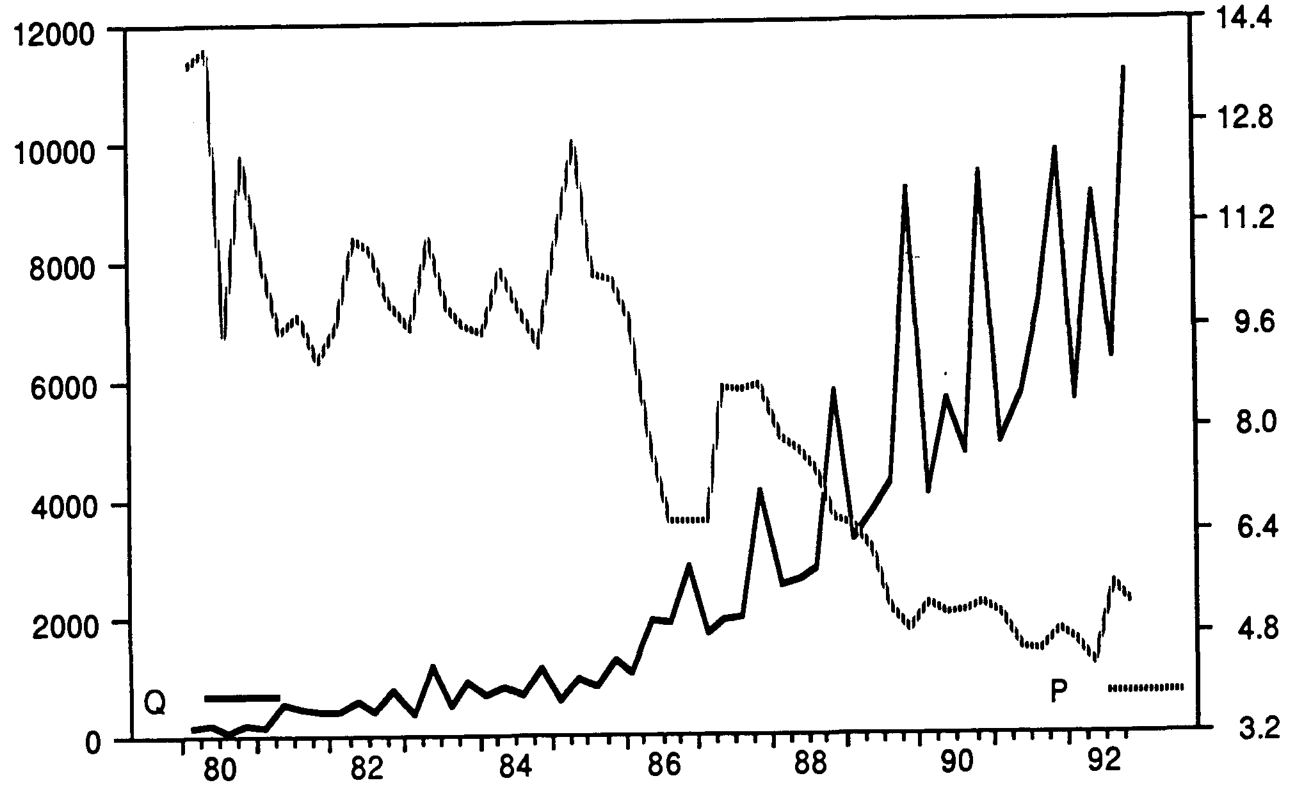
Salmon is commonly consumed as part of the Christmas celebration; hence the peaks in the quantity series the last quarter every year. There is a smaller peak in the middle of the

[7]For a more comprehensive treatment of the verdict and the case see Steen (1994c).

[8]The EU Commission, legal document 30, July 1992 No. L, (92/444/EØF), pp. 246/37-246/45, *Trade policy Review*, European Communities, volume I, 1993, GATT, pp. 125-126 and Press Report from EU August 3, 1992 (Ref.:IP/92/673).

Figure 1

Quarterly Norwegian quantity (Q) and price (P) of fresh salmon sold in France the period from 1981 to 1992.



summer, too. One of the reasons for this is the French tradition of having both religious and family celebrations in May/June.

The traditional distribution channel for imported fresh salmon has been from importer via a wholesaler (e.g. at Rungis in Paris, the largest market for agricultural products and wet fish in Europe) to retail outlets like specialised fish stores and restaurants. There has been at least two main changes in the distribution pattern. First and most important, the share of fish products distributed via super/hypermarkets increased from 21% in 1980 to 40% in 1989. At the same time the specialised fish stores reduced their share from 40 to 30% (Bjørndal, Salvanes, & Andreassen, 1992). Hence, salmon now compete more directly with other products, and this may have lead to changes in elasticities as more substitutes are available to the consumer.

France has also a considerable salmon smoking industry, which in addition to frozen salmon, also use fresh salmon as input. Of the total quantity of smoked salmon consumed in France, between 70 and 80% is domestically produced (Monfort, 1992).

Earlier studies on market structure have taken different views. Bjørndal and Schwindt (1989) conclude that there is a competitive market. They argue against the co-ordinated unit view, on the basis of several observations. First, Norway's market share of the world production of wild and farmed salmon is relatively low.[9] Second, neither producers nor consumers seem to have preferences regarding trade partners, and exporters buy fish from not one, but several farmers.

Due to Norway's dominant position in the farming industry, models in which Norway is assumed to have monopoly power have also been suggested (Singh, 1988). The problem with this view is that as long as there exist substitutes to Norwegian salmon, a monopoly model is not appropriate. Others have suggested that models with segmented markets should be applied (DeVoretz & Salvanes, 1988; Herrmann & Lin, 1988a; 1988b). Both of Herrmann and Lin's studies assume that the EU and the US are two different segments. By basically estimating demand models for each market segment and interpreting the results, they find support for a non-competitive market structure. DeVoretz and Salvanes (1993) modelled the market structure problem more explicitly and tested models with varying degrees of market power including third-degree price discrimination. They found that Norwegian exporters only had limited ability to engage in regional price discrimination. More specifically, they did not find significant differences in demand elasticities between the markets in the US and Europe, and concluded that the observed differences in CIF prices were explained by differences in transportation costs. However, they found that discrimination may have taken place after the third quarter in 1987. They also found that seasonal price discrimination could have taken place in that a mark-up was taken in the periods when fresh wild-caught salmon was unavailable.[10]

After summarising the results from these studies, and analysing the market characteristics, Bjørndal & Salvanes (1992) conclude that the market is competitive in the long-run, but that Norway may have some possibility to engage in intertemporal price

[9]Farmed salmon's market share of world production of salmon has been steadily increasing, in 1980 it was less then 1%, in 1992 it had grown to 27%, the average over this period was 11.3% (Bjørndal & Salvanes, 1992; Steen, 1994c).

[10]On average the period from 1981 to 1992 as much as 84% of North American fresh salmon was sold to the EU in the period January and the last five months of the year. This is the period that coincides with the most important salmon runs (Steen, 1994a).

discrimination. Further, since new entrants face growt-out periods of 2 to 3 year, they argue that there may be some room for exercising market power in the short-run.

A problem with the segmented market view is that as long as one has no clear cut definition of what the segments are, the models must be based on more or less *ad hoc* definitions of the market segments, which could undermine the empirical tests undertaken. Market delineation tests of the EU and the French market for fresh salmon suggest that the EU is an integrated market (Steen, 1994b). Further, tests for intertemporal price discrimination conclude that intertemporal changes in competition matter, but not to the extent that Norway is free to set prices on fresh salmon independently of other salmon products in the long-run (Steen, 1994a). These findings weaken the argument that Norway may have seasonal monopoly power and thus may have charged a mark-up in the fresh salmon market in the periods where wild-caught salmon was unavailable.

However, none of the earlier studies of this market have actually modelled market structure explicitly in terms of an oligopoly model, and none of them utilise dynamic models. Thus, the present analysis will give us a better opportunity to test the market power hypothesis more directly.

4.3. The Bresnahan-Lau Model

4.3.1 The Theoretical Model

The demand side may be described by the function[11];

(1) $$Q = D(P, Z; \alpha) + \varepsilon,$$

where Q is quantity, P is price and Z is a vector of exogenous variables affecting demand, e.g. a substitute price and income. The α's is the vector of parameters to be estimated and ε is the error term.

[11]This section is based on Bresnahan (1982) and Lau (1982). Bresnahan formulated the principle of identification whereas Lau gave the proof for under which conditions the identification was possible.

The supply side is more complex. When sellers are price takers, price equals marginal costs, and we can write;

(2) $P = c(Q,W;\beta) + \eta$,

where W are exogenous variables on the supply side, e.g. factor prices, β the supply function parameters, and η is the supply error. Marginal cost is given by $c(\cdot)$. However, when firms are not price takers, perceived marginal revenue, and not price, will be equal to marginal cost. Instead of a supply curve we now may write a supply relation;

(2') $P = c(Q,W;\beta) - \lambda \cdot h(Q,Z;\alpha) + \eta$,

where $P + h(\cdot)$ is marginal revenue, and $P + \lambda \cdot h(\cdot)$ is marginal revenue as perceived by the firm.[12] Hence, λ is a new parameter that may be interpreted as a summary statistic measuring the degree of market power. Under perfect competition, $\lambda = 0$ and price equals marginal cost. When $\lambda = 1$ we face a perfect cartel, and when $0 < \lambda < 1$ various oligopoly regimes applies. When looking at industries at an aggregated level, $\lambda = 1/n$ is interpreted as the Cournot case where n is the number of equally sized firms in the industry. Loosely speaking, λ is the percentage of monopoly marginal revenue perceived. The demand side parameters and the exogenous variables are included in $h(\cdot)$ because they affect marginal revenue.

[12]At industry level the profit maximisation problem is: $\text{Max}_Q \Pi = Q \cdot D^{-1}(Q) - C(Q)$, where $D^{-1}(Q)$ is the inverse demand function, $C(Q)$ the cost function (Z, W, α and β are excluded to simplify). The profit maximisation first order condition is; $g(Q) + (\partial g(Q)/\partial Q)Q - \partial C(Q)/\partial Q = 0$ or $P = \partial C(Q)/\partial Q - (\partial D^{-1}(Q)/\partial Q)Q$. The firm receives a fraction λ of the profit, i.e., $P = \partial C(Q)/\partial Q - \lambda \cdot (\partial D^{-1}(Q)/\partial Q)Q$, which is the same as (2') where $h(\cdot) = (\partial D^{-1}(Q)/\partial Q)Q$, and $c(\cdot) = \partial C(Q)/\partial Q$.

4.3.2 The Static Linear Model and the Identification Principle

The general empirical problem in all market structure studies is how to identify λ. Bresnahan solved this by introducing variables that combine elements both of rotation and of vertical shifts in the demand curve. This is done by formulating an interaction term between P and Z, i.e., changes in a substitute price affects both the position and the slope of the demand curve. To provide the necessary intuition of the identification principle used, we first formulate the simplest version of the static linear BL model.

Assuming both demand and marginal cost to be linear, the demand function (1) can be written as;

(3) $$Q = \alpha_0 + \alpha_P P + \alpha_Z Z + \alpha_{PZ} PZ + \varepsilon,$$

and the marginal cost function is;

(4) $$MC = \beta_0 + \beta_Q Q + \beta_W W.$$

The supply relation is now given as;

(5) $$P = \beta_0 + \beta_Q Q + \beta_W W - \lambda\left[\frac{Q}{\alpha_P + \alpha_{PZ} Z}\right] + \eta,$$

since $MR = P + [Q/(\alpha_P + \alpha_{PZ} Z)]$. By treating α_P and α_{PZ} as known (by first estimating the demand equation in (3)), λ is now identified in (5). To see this, write $Q^* = -Q/(\alpha_P + \alpha_{PZ} Z)$. There are two included exogenous variables, Q and Q^* and there are two excluded exogenous variables Z and W in (5). Hence, λ is identified as the coefficient of Q^* based on the estimation of (5). The inclusion of the rotation variable PZ in the demand function is crucial for this result. Exclusion of PZ from (3) makes $Q^* = -Q/\alpha_P$ and thus indistinguishable from

Q in the supply relation.[13] The economic implication of including this rotation variable in the demand equation is that the demand function is not separable in Z. Lau (1982) shows that identification is possible as long as this is true, regardless of the functional form chosen.[14]

The economic intuition behind this result is quite straightforward. Suppose that the exogenous variables entering demand rotate the demand curve around the industry equilibrium point. Under perfect competition, this will have no effect: supply and demand intersect at the same point before and after the rotation. Under any oligopoly or monopoly theory, changes in the slope (and thus the elasticity of demand) will shift the perceived marginal revenue of firms. Equilibrium price and quantity will respond. Hence, the market comparative statics of perfect competition are distinct from those of monopoly (Bresnahan, 1989).

4.4. The Bresnahan-Lau Model in an Error Correction Framework

Markets are inherently dynamic. Firms recognise their own ability to influence the market structure, and thereby the degree of competition. With influence on the market structure, price and/or quantity become strategic decision variables, resulting in various oligopoly regimes. This has been extensively modelled in game theory, and recently also in empirical applications, e.g. state-space models (Hall, 1990; Karp & Perloff, 1989; Karp & Perloff, 1990; Reynolds, 1986; Slade, 1990). In these studies one explicitly formulates dynamics as feedback and open-loop strategies, postulating a particular oligopoly regime.

Here we propose a dynamic reformulation of the BL model in an ECM framework. The most common motivation for using this framework is the statistical importance of accounting for short-run dynamics in the data. Further the framework solves the inference

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[13] To see this, exclude *PZ* from (3) and rewrite (5) as; $P = \beta_0 + \gamma Q + \beta_W W + \eta$, where $\gamma = \beta_W - \lambda/\alpha_P$. The supply relation is still identified but we would not know whether we were tracing out *P=MC* or *MR=MC*. The parameter we can estimate, γ, depends on both β_W and λ, which we obviously do not know.

[14] Lau (1982) provides a mathematical proof for the so-called *'Impossibility theorem'*, i.e., identification of the degree of competition from industry price and output data is impossible if and only if the inverse demand function is separable in a vector Z of exogenous variables.

problem when using non-stationary data.[15] The ECM formulation allows for short-run departure from long-run equilibrium in the data. Short-run deviations may be caused by factors such as random shocks, sticky prices, contracts etc., and in addition it may also be the result of seasonal shifts in supply and demand. However, by including lagged observations of the endogenous variables the ECM framework incorporates also dynamic factors such as habit formation from the demand side and adjustment costs for the producer. The presence of habit formation in demand and adjustment costs in supply make static models inadequate (Lucas, 1967; Phlips, 1983; Pollak & Wales, 1992). Hence, the ECM framework provides a solution both to statistical problems generated by short-run dynamics in the data and inclusion of important dynamic factors.

However, (as only lagged observations are included,) the framework imposes some restrictions on possible strategic behaviour by the firm. This may be seen by investigating the firm's profit maximisation problem, when also lagged endogenous variables are included. Present value of profits is given by

$$(6) \qquad \Pi = \sum_{t=1}^{\infty} \{ Q_t \cdot g(Q_t, Q_{t-1}) - C(Q_t, Q_{t-1}) \} \delta^t ,$$

where $g(Q_t,Q_{t-1})$ is the inverse demand function accounting also for habit formation, $C(Q_t,Q_{t-1})$ is the cost function accounting also for adjustment costs and δ^t is the discount factor. To simplify the exposition, exogenous variables, i.e., substitute prices, income and factor prices, are excluded from (6). The profit function in (6) is maximised by taking the first derivative of the sum in (6) with respect to Q at period t;

$$(7) \qquad \begin{aligned} &\partial \Pi / \partial Q_t = 0 \\ &\Rightarrow g(Q_t, Q_{t-1}) + Q_t g'(Q_t, Q_{t-1}) - C'(Q_t, Q_{t-1}) + Q_{t+1} g'(Q_{t+1}, Q_t) - C'(Q_{t+1}, Q_t) = 0 \end{aligned}$$

The two last terms follow from the fact that both the production today and the production tomorrow is endogenous to the firm at time t. The ECM formulation only includes lagged

[15] If time series are non-stationary, the standard OLS assumptions do not hold, i.e., the variance is biased.

observations of the endogenous variable. Hence, by using the ECM formulation we assume these two last terms to be zero, $(Q_{t+1}g'(Q_{t+1},Q_t) - c'(Q_{t+1},Q_t) = 0)$. Another way of interpreting this is that the firm is *myopic* when choosing what quantity to produce. This reduces the model's ability to uncover strategic behaviour between periods, as the intertemporal information is captured only through past observations.

As can be seen from (6), this is the aggregate profit. In the model we focus on Norway's role as an aggregate producer, modelling Norway as a dominant firm that set the profit maximisation price which the competitive fringe takes as given. The BL model allows for identifying a mark-up measure, indicating the degree of market power exercised. However, we neglect possible dynamic interaction between the fringe and the dominant firm. Hence, the fringe's behaviour is regarded as exogenous to the dominant firm's maximisation problem.

4.4.1 The ECM Formulation

The classical approach to dealing with integrated variables has been to difference them as many times as needed to make them stationary. This approach has the merit of simplicity. Once all series have been transformed to stationarity, dynamic regression models may be specified in the usual way, and standard asymptotic results apply. The problem with this approach is that differencing eliminates the long-run information contained in the levels of the variables. An alternative approach is to estimate an error-correcting model. The economic interpretation of an error correcting model makes this a preferable alternative. Economic processes can usually be described by a long-run equilibrium relation, but where deviations from this long-run relation may be observed in the short-run. A model capturing this effect is thus meaningful to use.

If there exists a stable equilibrium between the two time series x_1 and x_2, e.g. $x_1 = \beta x_2$, the $\{x_{1,t} - \beta x_{2,t}\}$ evidently contains useful information since on average the system will move towards that equilibrium if it is not already there. In particular, $\{x_{1,t-1} - \beta x_{2,t-1}\}$ represents the previous disequilibrium, and is usually referred to as an error-correcting mechanism which is often included in dynamic regressions (Hendry & Anderson, 1977; Sargan, 1964). The demand function in (3) in ECM form can be written as

$$\text{(8)} \qquad \Delta Q_t = \alpha_0 + \sum_{i=1}^{k-1} \alpha_{Q,i} \Delta Q_{t-i} + \sum_{i=0}^{k-1} \alpha_{P,i} \Delta P_{t-i} + \sum_{i=0}^{k-1} \alpha_{Z,i} \Delta Z_{t-i} + \sum_{i=0}^{k-1} \alpha_{PZ,i} \Delta PZ_{t-i}$$
$$+ \gamma^* [Q_{t-k} - \theta_P P_{t-k} - \theta_Z Z_{t-k} - \theta_{PZ} PZ_{t-k}] + \varepsilon_t$$

where

$$\text{(9)} \qquad \theta_j = \alpha_j^* / \gamma^*, \quad \text{and} \quad j = P, Y, Z, PZ.$$

How the ECM formulation relates to the autoregressive distributed lag (ADL) model, and the interpretation of the parameters are presented in detail in Appendix B. The summations capture the short-run dynamics, (and the short-run parameters). The bracket parenthesis is the ECM term which provides the stationary long-run solution, e.g. the parameter θ_P measures the stationary long-run impact from P_t on Q_t. γ^* is usually denoted as the adjustment parameter and measures the impact on ΔQ_t of being away from the long-run target; that is, γ^* measures to what extent firms tend to correct the errors of past decisions.

There are several reasons for a dynamic formulation of the demand function. In particular factors such as habit formation and structural change are shown to be important in demand studies (Phlips, 1983; Pollak & Wales, 1992; Asche, Salvanes, & Steen, 1994). Further, this approach accounts for autocorrelation and non-stationarity. The latter is seen directly from (8): Assuming that the variables are stationary in their first differences, all the summations are stationary and, if the variables cointegrate, also the linear combination in the parenthesis is stationary.

To identify the supply relation and λ, some of the demand parameters, e.g. price and interaction parameters, are needed. The natural candidates are the long-run parameters: θ_P

and θ_{PZ} (see Appendix B). Hence, the dynamic formulation of the supply relation in (5) is;

$$(10)\quad \Delta P_t = \beta_0 + \sum_{i=1}^{k-1} \beta_{P,i} \Delta P_{t-i} + \sum_{i=0}^{k-1} \beta_{Q,i} \Delta Q_{t-i} + \sum_{i=0}^{k-1} \beta_{W,i} \Delta W_{t-i} + \sum_{i=0}^{k-1} \lambda_i \Delta Q^*_{t-i}$$
$$+ \psi^* \left[P_{t-k} - \xi_Q Q_{t-k} - \xi_W W_{t-k} - \Lambda Q^*_{t-k} \right] + \eta_t,$$

where

$$(11)\quad Q^*_t = Q_t \Big/ (\theta_P + \theta_{PZ} Z_t)$$

and

$$(12)\quad \Lambda = \lambda^* \big/ \psi^*, \quad \xi_Q = \beta^*_Q \big/ \psi^*, \quad \xi_W = \beta^*_W \big/ \psi^* .$$

How the supply relation relates to the ADL formulation, and the interpretation of the parameters are presented in Appendix B. The ECM formulation provides both a short-run measure of λ: λ_0, and a long-run measure, Λ. The supply relation in (10) incorporates adjustment costs and allows short-run deviations from the requirement that marginal cost should equal perceived marginal revenue, factors shown to be important in cost studies (Lucas, 1967; Friesen, 1993). Further, it solves the same statistical problems as the dynamic demand specification.[16]

4.4.2. Empirical Specification

The product of interest is Norwegian fresh salmon sold in France. To represent the exogenous Z vector we use a substitute price and an income variable. Based on earlier demand studies of

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[16]There exists several demand studies utilising ECM models (Bentzen & Engsted, 1992; Denbaly & Vroomen, 1993; Asche, Salvanes & Steen, 1994). Asche *et al.* (1994) estimate a demand system on ECM form for salmon and crustaceans in the EU market. .Friesen (1992) uses the ECM framework in a cost study.

this market, the price of frozen Pacific salmon from North America salmon is chosen (Asche, Salvanes & Steen, 1994; DeVoretz & Salvanes, 1993). Private consumption is used to represent income. In the model income is denoted as *Y*. Two cost components are used to formulate marginal cost; Norwegian average feed price (*W1*), and a wage index (*W2*) based on average wages in the salmon farming industry and the average unit cost of labour in manufacturing. Wages, feed costs, capital and smolts are the main cost components in salmon farming (Salvanes, 1989; Salvanes, 1992; Salvanes & Tveterås, 1992).[17] Wages and feed costs accounted for between 45 and 55% of total costs in the period from 1986 to 1990 (Salvanes & Tveterås, 1992). (See appendix A for a precise description of the data set and the variable definitions.)

Preliminary Tests: Integration and Cointegration tests

Before specifying the empirical model we test the variables integration order using Dickey-Fullers Augmented unit root test (Dickey & Fuller, 1979; Dickey & Fuller, 1981). All variables are found to be non-stationary in the levels, but stationary in the first differences at reasonable significance levels. Hence, the summations of first differences capturing the short-run dynamics in (8) and (10) are stationary. The results are presented in Table 1.

Table 1

Augmented Dickey-Fuller tests for integration order (n=48).[1]

		I(0)	Lag	I(1)	Lag
Q	fresh salmon quantity	-1.43	4	-4.10*	4
p	fresh salmon price	-2.34	5	-14.82*	0
Z	frozen salmon price	-2.42	6	-5.38*	1
Y	private consumption	-2.95	3	-109.45*	0
W1	feeding cost	-2.68	0	-3.33***	3
W2	wage index	-2.47	4	-7.33*	2

*/significance at a 2.5% level, **/significance at a 5% level, ***/significance at a 10% level.
[1]/Critical values are from Fuller, (p. 373, 1976).

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[17]These four components represent between 74 and 84% of total costs during the period from 1986 to 1990 (Steen, 1994c).

To ensure the existence of a long-run solution we now test for cointegration using the multivariate cointegration test of Johansen and Juselius (Johansen, 1988; Johansen, 1991; Johansen & Juselius, 1990). To find the possible stationary linear combinations, the cointegration vectors, the data is divided into two groups, the variables in levels, and their first differences. Under the assumption of $I(1)$ processes, the differenced data are stationary. Using the technique of canonical correlation from the theory of multivariate analysis, the linear combinations of the data in levels which are highly correlated with the differences are found. If the correlation is sufficiently high, it follows that these linear combinations are stationary, and so are the cointegration vectors.

More formally, the vector of N variables $\mathbf{x}_t$ is assumed to be generated by an unrestricted vector autoregression (VAR) in the levels of the variables,

(13) $$\mathbf{x}_t = \Pi_1\mathbf{x}_{t-1}+\ldots+\Pi_k\mathbf{x}_{t-k} + \Phi D_t + \mu + \varepsilon_t,$$

where each of the Π_i is an $(N \times N)$ matrix of parameters, D_t are seasonal dummies orthogonal to the constant term μ and $\varepsilon_t \sim niid(0,\Omega)$. The VAR-system of equations in (13), written in error correction form, is

(14) $$\Delta\mathbf{x}_t = \sum_{i=1}^{k-1}\Gamma_i\Delta\mathbf{x}_{t-i} + \Pi_K\mathbf{x}_{t-k} + \Phi D_t + \mu + \varepsilon_t,$$

with $\Gamma_i = -I + \Pi_1+\ldots+\Pi_i$, $i = 1,\ldots,k-1$. Hence, Π_K is the long-run 'level solution' to (13). If $\mathbf{x}_t$ is a vector of $I(1)$ variables, the left-hand side and the first $(k-1)$ elements of (14) are $I(0)$, and the Kth element of (14) is a linear combination of $I(1)$ variables. Given the assumption on the error term, this last element must clearly also be $I(0)$; $\Pi_K x_{t-k} \sim I(0)$, hence $\mathbf{x}_t$ either 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 $\mathbf{x}_t$ are stationary. If r=N, the variables in levels are stationary; if r=0 so that Π_K=0, none of the linear combinations are stationary. When 0< r<N , r cointegration vectors, or r stationary linear combinations of $\mathbf{x}_t$ exist . In this case one can factorize Π_K; $-\Pi_K = \alpha\beta'$, where both β and α are $(N \times r)$

matrices, and β contains the cointegration vectors and α the adjustment parameters. It is possible to test for the number of significant vectors using two different tests, the 'trace' test and the 'maximal eigenvalue' test. The trace test (η_r) is a likelihood ratio test for *at most r cointegrating vectors;* $\eta_r = -T\sum_{i=r+1}^{N}\ln\left(1-\hat{\lambda}_i\right)$, where T is number of observations and the $\hat{\lambda}_i$ are the eigenvalues that solve the eigenvalue problem. The maximal eigenvalue test (ξ_r), is a test of *the relevance of column* r+1 *in* β; $\xi_r = -T\ln\left(1-\hat{\lambda}_{r+1}\right)$.

We need to ensure the existence of a long-run solution in both the demand function and the supply relation. Thus, we undertake two cointegration tests, one representing the demand function in (8) and one representing the supply relation in (10). Hence, the matrix of variables in (14), $\mathbf{x}_t$, consists of the variables Q, P, Z,Y, PZ and PY for the demand function, and the variables Q, P, $W1$, $W2$ and Q^* for the supply relation.[18]

To account for the possible simultaneity problem, the cost shifters, $W1$ and $W2$, are included as predetermined variables in the VAR system representing the demand function, and Z is included as predetermined in the VAR system representing the supply relation. The simultaneity problem here is how to control for movements in the supply curve when estimating the demand curve, and analogously, how to control for demand when estimating the supply relation. For instance, it is only if we know that supply is either perfectly elastic or inelastic that we assume a quantity or price dependent model, and can identify the demand function without using exogenous supply shifters. It is not obvious that we are in any of these situations in the salmon market. An advantages of fish farming over capture fisheries is the greater flexibility in harvesting. Hence, one would expect that the farm gate price is an important factor determining harvest rates and suggests an elastic supply (Bjørndal, *et al.*, 1992). Instrumental variable methods are used to solve this problem.

We find clear indication of cointegration in both cases. The results are shown in Table 2. The trace test indicates four cointegration vectors for the demand function, and three cointegration vectors in the supply relation. The more conservative maximal eigenvalue tests indicate two cointegration vectors in both cases (5% significance level). Hence, the linear

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[18]We calculate Q^* from (11) using parameters from the demand function in (15) estimated in section 5 (see Table 5).

combination in the ECM parantheses in (8) and (10) represent cointegration relations, and can thus be interpreted as stationary long-run solutions.

Table 2

Multivariate cointegration tests based on the VAR system in (14), critical values η_r and $\xi_r (n=48)$.

	ξ_r	η_r
	Demand function/a	
1 cointegration vector $r=0$	62.63*	162.89*
2 cointegration vectors $r=1$	35.40**	100.26*
3 cointegration vectors $r=2$	25.38	64.87*
4 cointegration vectors $r=3$	21.91	39.49*
5 cointegration vectors $r=4$	12.71	17.58
6 cointegration vectors $r=5$	4.87	4.87
	Supply relation/b	
1 cointegration vector $r=0$	42.63 *	118.45*
2 cointegration vectors $r=1$	36.75*	75.82*
3 cointegration vectors $r=2$	21.56***	39.07*
4 cointegration vectors $r=3$	13.03	17.51
5 cointegration vectors $r=4$	4.49	4.49

*/ Significant at a 2.5% level, **/ significant at a 5% level, ***/ significant at a 10% level, , the critical values are from Osterwald-Lenum, (1992).
a/ The lag length in (12) is here $k = 2$.
b/ The lag length in (12) is here $k = 4$.

Separabillity Tests

As shown in section 3.2, to identify λ we need the demand function *not* to be separable in Z. In the literature one can find various empirical specifications of Z. Buschena and Perloff (1991) use two time trends to represent Z in their study of the coconut oil market. Suominen

(1991) and Shaffer (1993) include income in addition to the interaction term between price and substitute price. Alexander (1988) uses only the substitute price. It is enough with one variable to identify rotation in the MR curve. However, including additional interaction terms increase the accuracy of the identification, and will thus provide a better estimate of λ. Our Z vector consists of two exogenous variables. Hence, we have two possible variables that may rotate the MR curve, income and the substitute price, denoted Y and Z. Hence, to identify λ, using these two interaction terms we need the demand function *not* to be separable in *both* Z and Y. To test this hypothesis we utilise the exclusion tests in the Johansen-Juselius framework.

Exclusion tests are imposed as null-restrictions on the long-run parameter for PZ and PY in the $\hat{\beta}$ found to represent the demand function. Hence, if the interaction term can be excluded from the long-run relation the demand function is separable in Z and Y. The null restrictions on the parameters in $\hat{\beta}$ are tested using a likelihood ratio test. First we estimate the unrestricted model and solves the eigenvalue problem, then the model with the restriction(s) imposed are estimated and the restricted eigenvalues $\hat{\lambda}_1^* > ... > \hat{\lambda}_r^*$ are calculated. Finally, the test statistics are calculated as: $LR^*[r(N-s)] = T\sum_{i=1}^{r} \ln\left\{1-\hat{\lambda}_i^*/1-\hat{\lambda}_i\right\}$. The test statistic has an asymptotic chi-square distribution with $r(N-s)$ degrees of freedom, where s is the number of independent cointegration parameters in the restricted model (Hamilton, 1994; Johansen & Juselius, 1990).

Both joint and individual tests are undertaken. The joint null-hypothesis is; $H_0\!:\hat{\beta}_{PZ} = \hat{\beta}_{PY} = 0$; *the demand function is separable in Z and Y*. The two individual hypotheses of separability in Z and Y follow analogously. Note that since there is more than one cointegration vector all corresponding parameters across the vectors must be tested. With two cointegration vectors as here, the joint null hypothesis is; $H_0\!:\hat{\beta}_{1,PZ} = \hat{\beta}_{2,PZ} = \hat{\beta}_{1,PY} = \hat{\beta}_{2,PY} = 0$.

The results are shown in Table 3. In the individual tests for separability in Z and Y, the null-hypotheses of separability are rejected at a 2.5% significance level in both cases. The joint hypothesis of separability in *both* Z and Y is rejected at an even higher significance level;

1%.[19] This is as expected since the joint null hypothesis is more restrictive then the two independent hypotheses. Hence, the demand function is not separable in Z and Y, and we can use both interaction terms, PZ and PY to identify λ.

Table 3

Separability tests

Individual separability tests		Joint separability test
$H_0\text{:}\beta_{1,PZ} = \beta_{2,PZ} = 0$	$H_0\text{:}\beta_{1,PY} = \beta_{2,PY} = 0$	$H_0\text{:}\beta_{1,PZ} = \beta_{2,PZ} = \beta_{1,PY} = \beta_{2,PY} = 0$
8.74^{**}	7.87^{**}	26.74^{*}

*/significance at a 1% level, **/significance at a 2.5% level. In the individual tests there are 2 degrees of freedom; $r(N-s) = 2(7-6) = 2$, and in the joint test there are 4 degrees of freedom; $r(N-s) = 2(7-5) = 4$.

The Empirical Model

Based on the integration, cointegration and separability tests we have ensured inference, the existence of a stationary long-run solution and identification of the market power parameter. However, before we formulate the equations to be estimated, some additional characteristics of the salmon market must be considered. First, there is reason to believe that a structural shift appeared in the salmon market in the third quarter of 1989 (Asche, Salvanes & Steen, 1994).[20] This shift is accounted for using a dummy variable in the demand function which is zero until the third quarter 1989, and takes the value one afterwards (*SHFT89*). Previous salmon demand studies show that seasonality is important in this industry (Bjørndal, et al., 1992; DeVoretz & Salvanes, 1993; Herrmann & Lin, 1988a). Hence in addition to the constant term and the shift dummy, also three seasonal dummy variables are included ($D_{t,i}$). The demand function in (8)

[19]All three tests are based on the cointegration relations shown in Table 2.

[20]Several factors may have induced this shift. By 1989 the French market for salmon was characterised by excess supplies, and rapidly declining prices due to the particularly strong increase in North American wild salmon harvest and farmed salmon production. Further, a huge freezing program was initiated in Norway which is the main supplier of fresh salmon in France. Finally, the bad publicity for wild-caught salmon following the Exxon Valdez accident in Alaska may also have been a factor (Asche, Salvanes & Steen, 1994; Herrmann & Greenberg, 1992).

may then be extended to:

$$(15)\quad \Delta Q_t = \alpha_0 + \sum_{i=1}^{3} D_{t,i} + SHFT89_t + \sum_{i=1}^{k-1} \alpha_{Q,i}\Delta Q_{t-i} + \sum_{i=0}^{k-1} \alpha_{P,i}\Delta P_{t-i} + \sum_{i=0}^{k-1} \alpha_{Y,i}\Delta Y_{t-i} + \sum_{i=0}^{k-1} \alpha_{Z,i}\Delta Z_{t-i}$$
$$+ \sum_{i=0}^{k-1} \alpha_{PZ,i}\Delta PZ_{t-i} + \sum_{i=0}^{k-1} \alpha_{PY,i}\Delta PY_{t-i} + \sum_{i=0}^{k-1} \Delta SHFT89_{t-i}$$
$$+ \gamma^*\left[Q_{t-k} - \theta_P P_{t-k} - \theta_Y Y_{t-k} - \theta_Z Z_{t-k} - \theta_{PZ} PZ_{t-k} - \theta_{PY} PY_{t-k}\right] + \varepsilon_t,$$

and the supply relation from (10) is now:

$$\Delta P_t = \beta_0 + \sum_{i=1}^{3} D_{t,i} + \sum_{i=1}^{k-1} \beta_{P,i}\Delta P_{t-i} + \sum_{i=0}^{k-1} \beta_{Q,i}\Delta Q_{t-i} + \sum_{i=0}^{k-1} \beta_{W1,i}\Delta W1_{t-i} + \sum_{i=0}^{k-1} \beta_{W2,i}\Delta W2_{t-i}$$
$$(16)\quad + \sum_{i=0}^{k-1} \lambda_i \Delta Q^*_{t-i} + \psi^*\left[P_{t-k} - \xi_Q Q_{t-k} - \xi_{W1} W1_{t-k} - \xi_{W2} W2_{t-k} - \Lambda Q^*_{t-k}\right] + \eta_t,$$

where *W1* is unit labour cost, *W2* is feed price, and Q_t^* includes information from both *Z* and *Y*, i.e., $Q_t^* = Q_t/(\theta_P + \theta_{PZ}Z_t + \theta_{PY}Y_t)$. All prices and values are in real terms and the error terms are assumed to have the standard properties.[21]

Equations (15) and (16) are non-linear in their parameters, and therefore require a non-linear estimation procedure. However, by removing the ECM parentheses one obtains linearity, and it is possible to use standard OLS. The main difference is that instead of getting the long-run parameters directly from the estimation, the long-run parameters are found by dividing all the estimated level parameters by γ^* (15) and Ψ^* (16).[22] This is the Bårdsen transformation, and will be applied here (Banerjee, Dolado, Galbraith, & Hendry, 1993; Bårdsen, 1989). Hence, the estimation is done in two steps. To account for the simultaneity problem, (15) is estimated using an instrumental variable technique, two stage least squares (2SLS), using *W1, W2* and a linear time trend as instruments.[23] Then, after having calculated the Q^* variable, (16) is estimated using the same technique, with *Z* and a linear time trend as

[21]Note that both the level of the shift-dummy and its difference is included in (15). Even though the constant term in the short run dynamics, α_0, disappears when the first difference is taken, the shift-dummy will have four data points where it is one, and accordingly it must be included.

[22]In the demand function this means to estimate γ^* and α_j^*, and calculate θ_j afterwards using (9), as opposed to estimate θ_j directly, *j=P,Y,Z,PZ,PY*. The procedure applies analogously for the supply relation.

[23]The econometric package SHAZAM was used (White, 1978).

instruments.

To be able to compare the dynamic model with the static model, we also estimate a static linear BL model. Except for the lagged variables, we use the same specification as the model described by (15) and (16). Thus, the static demand function is;

$$(17)\qquad Q_t = \alpha_0 + \sum_{i=1}^{3} D_{t,i} + SHFT89_t + \alpha_P P_t + \alpha_Y Y_t + \alpha_Z Z_t + \alpha_{PZ} PZ_t + \alpha_{PY} PY_t + \varepsilon_t,$$

and the static supply relation is;

$$(18)\qquad P_t = \beta_0 + \sum_{i=1}^{3} D_{t,i} + \beta_Q Q_t + \beta_{W1} W1_t + \beta_{W2} W2_t + \lambda_{static} Q_t^{*(static)} + \eta_t,$$

where $Q_t^{*(static)} = Q_t / (\alpha_P + \alpha_{PZ} Z_t + \alpha_{PY} Y_t)$, and we use the same two step procedure as for the model in (15) and (16). The same instrumental variable technique, and the same instruments are used, too. However, note that since our integration tests showed that the variables are non-stationary, standard inference does not apply, and standard errors of the parameters should not be used for testing.

4.5. Empirical Results

The Demand Function

We will start by presenting the results for the demand function (equation 15) in Table 4. The Ljung-Box Q-statistics was used to decide the lag length to k=2 in order to avoid higher-order autocorrelation (Ljung & Box, 1979).[24] The model fits well with $R^2 = 0.87$. However, several parameters are insignificant. The correlations between the right hand side variables are very high.[25] Hence, the combination of low parameter significance together with high

[24]The Q-statistics clearly reject autocorrelation: Q(4)=3.48, Q(8)=3.78 and Q(12)=7.53.

[25]When we are looking at the five main variables; *P, Z, Y, PZ* and *PY*, there is a total of 10 correlation coefficients, 6 are higher than 0.8, 8 are higher than 0.7 and none is lower than 0.54.

explanatory power is ascribed to problems of multicollinearity.

Table 4

2SLS estimates of the demand function in (15), quarterly data from 1981 to 1992 ($k = 2$).

	Parameter	St. Dev.
α_0	-60762.00	67460.00
$D_{t,1}$	-2263.20	2252.00
$D_{t,2}$	-222.71	2036.00
$D_{t,3}$	-1925.30	2279.00
$\alpha_{Q,1}$	-1.45	0.25
$\alpha_{P,0}$	-14580.00	25180.00
$\alpha_{P,1}$	-5240.70	15840.00
$\alpha_{Y,0}$	-20.13	49.76
$\alpha_{Y,1}$	22.03	13.56
$\alpha_{Z,0}$	-3363.10	3963.00
$\alpha_{Z,1}$	-86.48	1761.00
$\alpha_{PZ,0}$	416.97	486.10
$\alpha_{PZ,1}$	55.75	246.10
$\alpha_{PY,0}$	2.95	5.63
$\alpha_{PY,1}$	1.20	3.68
γ^*	-2.07	0.61
$\alpha^*_{P,2}$	3454.00	9111.00
$\alpha^*_{Y,2}$	20.52	13.83
$\alpha^*_{Z,2}$	-1167.40	1768.00
$\alpha^*_{PZ,2}$	173.63	267.80
$\alpha^*_{PY,2}$	-1.41	1.82
$\Delta SHFT89_t$	-1737.90	1682.00
$\Delta SHFT89_{t-1}$	1468.80	1747.00
$SHFT89_{t-2}$	-695.86	1999.00
R^2 between observed and predicted	0.87	

In Table 5 we have presented the long-run parameters calculated by using (9). The signs in Tables 4 and 5 cannot be directly interpreted due to the interaction terms *PZ* and *PY*. These terms must be considered together with the coefficients on P, Z and Y, since two coefficients are included in the calculation of the elasticities. Hence, to validate the model we investigate the stationary long-run elasticity predictions. The long-run own-price elasticity is given as $\varepsilon_{PP} = [\theta_P + \theta_{PZ}\overline{Z} + \theta_{PY}\overline{Y}] \cdot [\overline{P}/\overline{Q}]$, the cross-price elasticity is $\varepsilon_{PZ} = [\theta_Z + \theta_{PZ}\overline{P}] \cdot [\overline{Z}/\overline{Q}]$ and the income elasticity is $\varepsilon_{YY} = [\theta_Y + \theta_{PY}\overline{P}] \cdot [\overline{Y}/\overline{Q}]$. In Table 6 the long-run demand elasticities are presented.

Table 5

2SLS estimates of the long run parameters in the demand function in (15), quarterly data from 1981 to 1992 ($k = 2$).

	Parameter	St. Dev./a
θ_P	1666.30	4612.10
θ_Y	9.90	7.60
θ_Z	-563.17	797.70
θ_{PZ}	83.76	118.60
θ_{PY}	-.678	.958

a/Standard errors are calculated using a linear Taylor approximation, see also Bårdsen (1989).

Table 6

Long run estimates of demand elasticities from (15)

ε_{PP}	ε_{PZ}	ε_{YY}
-1.24	0.20	5.69

Fresh salmon is found to be own-price elastic, with a long-run own-price elasticity of -1.24. This is in line with what is usually found in the literature (Bjørndal, et al., 1992; DeVoretz & Salvanes, 1993; Herrmann & Lin, 1988a). Since we use Norwegian prices and quantities our demand function can be interpreted as the Norwegian residual demand curve, which is thus downward sloping. This suggests a non-competitive market structure (Baker & Bresnahan, 1988).[26] DeVoretz and Salvanes (1993) also used Norwegian data, and found the residual demand curve to have an even steeper negative slope in the EU. They used an instrumental variable technique including cost indices on wage, feed and capital as supply

[26]By residual demand curve, we mean the relationship between one firm's price and quantity, taking into account the supply response of all other firms. The residual demand curve of a firm in a perfectly competitive industry is flat, that of a monopolist is the same as the industry demand curve, and that of a firm in a product differenciated industry lies between these extremes (Baker & Bresnahan, 1988).

shifters, too. However, their model was static, and we use a longer and more recent data set.[27]

The long-run income elasticity of 5.69 suggests that fresh salmon is a luxury product. This is also in line with the literature (Andreassen, 1991; Bjørndal, *et al*., 1992; DeVoretz & Salvanes, 1993; Herrmann & Lin, 1988a). The elasticity estimate is somewhat higher than what one finds in most of the literature, although Andreassen (1991) actually found the income elasticity to be the same; 5.69.

The long-run cross-price elasticity of 0.20 suggests frozen North American salmon to be a substitute to Norwegian fresh salmon. This estimate is quite low. However, in both studies where North American frozen salmon is chosen as the substitute: Herrmann and Lin (1988) and DeVoretz and Salvanes (1993), different model specifications, different sample length, and different variable definitions, are used.[28] Herrmann and Lin—got a cross-price elasticity of 0.37, DeVoretz and Salvanes—found it to be 1.12.

A somewhat surprising result is the estimate of the adjustment parameter γ^* of -2.07. (see Table 4). It is expected that this parameter is in the range of -1 to 0. If $\gamma^* = 0$ no error correction takes place, if $\gamma^* = -1$, a deviation from the long-run equilibrium path is adjusted instantly. An estimate, $\gamma^* = -2.07$ is to be interpreted as overshooting, i.e., a deviation from the stationary long-run equilibrium is not only adjusted, but one overshoots. The 97.5% confidence intervall for γ^* includes -1; $[-3.34, -0.81]$, but the 95% confidence intervall does not include -1, and predicts persistent overshooting; $[-3.12, -1.02]$. There is no economically sound rationale for such a result in general. However, in this particular industry the rapid expansion in supply and demand: a more than 22 times increase of quantity over the sample period, seasonal shifts in both demand and supply, may have made it particularly difficult for the market participants to predict the development and thus the best strategy.[29] This may therefore lead to overshooting behaviour.[30]

[27] DeVoretz and Salvanes (1993) used quarterly data the period from 1983 to 1988.

[28] A problem with especially the earliest of these two studies is the immature nature of the salmon aquaculture industry during the time period investigated. Herrmann and Lin (1988) use lagged quantities in the supply equations to capture possible demand shifts. In a rapidly growing market this is insufficient to capture the decisions which go into production of farmed salmon, such as varying prices on inputs, changing technology and growing capital stock (Wessells & Anderson, 1992). The sample period in Herrmann and Lin's study was 1983 to 1987.

[29] Some authors have discussed the possible existence of cycles in the salmon industry (Chamberlain & Ritson, 1991; Ritson, 1993). Cycles in the form of hog-cycles will typically lead to overshooting behaviour.

[30] To test the robustness of this result, we estimated the model using different instruments, i.e., only *W1* or *W2*,

An explanation for the overshooting result, and the high income elasticity may also be how the model accounts for positive shifts in demand. We have included income as a shift variable. However, this variable increases by only 60% during the sample period. Hence, the outward shifts in demand cannot be fully explained by income. Due to changes in distribution channels, penetration of new market segments and increased concern about nutrition, demand has shifted outward. These factors are not modelled, and is thus only captured through the income variable. Hence, the estimated income elasticity captures more than changes in income and may therefore be too high. This may also explain the high adjustment parameter estimate.

We have also estimated the static demand function in (17). The results are presented in Table 7. The static model fits the data well. However, as expected, in the static model autocorrelation is a problem. When testing for autocorrelation, the Q-statistics conclude with autocorrelation; Q(4)= 9.19, Q(8)=16.44 and Q(12)=21.55. Further, the static elasticities are

Table 7

2SLS estimates of the static demand function in (17), quarterly data from 1981 to 1992.

	Parameter	St. Dev.
α_0	-118330	47690
$D_{t,1}$	-2395.4	473.8
$D_{t,2}$	-2138.6	561.1
$D_{t,3}$	-1980.4	458.4
$SHFT89_t$	-1620.2	1529.0
α_P	12506.0	5300.0
α_Y	29.2	10.4
α_Z	1183.8	1120
α_{PZ}	-164.9	140.9
α_{PY}	-2.9	1.1
R^2 between observed and predicted	0.89	
ε_{PP}^{SR}	-0.17	
ε_{PZ}^{SR}	-0.24	
ε_{YY}^{SR}	7.42	

different time trends, etc. However, the result of overshooting is persistent to use of different instruments.

quite different from what we found in the dynamic model. The static model predicts an inelastic market, with an own price elasticity of -0.17, and weak complimentarity between fresh and frozen salmon ($\varepsilon_{PZ}^{SR} = -0.24$). None of these two predictions have any support in the theory or in the present literature on salmon markets, suggesting that a static approach is inadequate in this market. The static income elasticity is even higher than the dynamic prediction ($\varepsilon_{YY}^{SR} = 7.42$). Hence, based on statistical and economic predictions, we conclude the use of a static model to be inadequate in this market.

The Supply Relation

In terms of the estimated elasticities, the dynamic demand function provides reasonable economic predictions, and it fits the data well. We now calculate the variable Q^* using the long-run parameters in Table 5, and estimate the supply relation (16).[31] Four lags were found sufficient to account for autocorrelation of higher order (k=4).[32] The results are presented in Table 8. As with the demand function the model fits well with an $R^2 = 0.77$. The adjustment parameter ψ^* is here in the interval between -1 and 0; $\psi^* = -0.66$, indicating an adjustment of 66% after deviations from the long-run equilibrium.[33]

It is not as straightforward to interpret the other parameters in the supply relation, but when looking at the parameter of interest; λ, also this provides reasonable predictions. As the empirical model is specified, the market power parameter should be negative, and between -1 and 0. If λ is 0, Norway behaves competitively, if λ is -1, Norway uses all its potential market power with respect to its residual demand curve. The short-run estimate of λ, is $\lambda_0 = -0.025$, suggesting that Norway exercises an intermediate level of market power in the short-run. To test this we formulate the null hypothesis; H_0^{SR}; $\lambda_0 = 0$, and the alternative hypothesis of market power; H_{ALT}^{SR}: $\lambda_0 < 0$. Using a standard t-test, we reject H_0^{SR} at a 5% significance level, not rejecting H_{ALT}^{SR} of market power in the short-run.

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[31]Since we primarily need unbiased predictions from the demand function to calculate a credible Q^* variable, the multicollinearity problem is not crucial to the analysis.

[32]The Q-statistics clearly reject autocorrelation; Q(4)=8.10, Q(8)=8.44 and Q(12)=13.18.

[33]The 5% confidence intervall of ψ^* is $[-1.03, -0.29]$, the 97.5% intervall is $[-1.10, -0.22]$.

Table 8

2SLS estimates of the supply relation in (16), quarterly data from 1981 to 1992 ($k = 4$).

	Parameter	St. Dev.
β_0	14.79	14.69
$D_{t,1}$	0.96	1.91
$D_{t,2}$	0.36	1.48
$D_{t,3}$	-1.65	1.70
$\beta_{P,1}$	-0.22	0.22
$\beta_{P,2}$	-0.62	0.24
$\beta_{P,3}$	-0.30	0.20
$\beta_{Q,0}$	-0.0004	0.0010
$\beta_{Q,1}$	-0.0006	0.0012
$\beta_{Q,2}$	-0.0009	0.0011
$\beta_{Q,3}$	-0.0006	0.0010
$\beta_{W1,0}$	-0.46	0.93
$\beta_{W1,1}$	-0.20	0.68
$\beta_{W1,2}$	0.23	1.07
$\beta_{W1,3}$	-0.22	1.85
$\beta_{W2,0}$	-0.24	0.18
$\beta_{W2,1}$	-0.03	0.22
$\beta_{W2,2}$	0.04	0.16
$\beta_{W2,3}$	-0.09	0.39
λ_0	-0.025	0.013
λ_1	-0.015	0.016
λ_2	-0.015	0.022
λ_3	-0.017	0.031
ψ^*	-0.66	0.21
$\beta^*_{Q,4}$	-0.0003	0.0002
$\beta^*_{W1,4}$	-0.16	1.01
$\beta^*_{W2,4}$	-0.08	0.07
λ^*_4	-0.033	0.029
R^2 between observed and predicted	0.77	

The next question is whether this result also holds in the long-run. In Table 9 the long-run parameters are presented. The long-run measure of λ, Λ, is also in the interval between -1 and 0; $\Lambda = -0.050$, predicting an even higher Norwegian mark-up. However, when testing the null hypothesis of no market power in the long-run; H_0^{LR}; $\Lambda = 0$, against the alternative hypothesis of market power; H_{ALT}^{LR}; $\Lambda < 0$, we cannot reject H_0^{LR} of no market power. This result applies whether we use a t-test or a the more general Wald test. A problem with the long-run test is that since the long-run parameters are non-linear transformations of the parameters in Table 8, we have to use linear Taylor-approximations to calculate standard errors (see Table 9). These standard errors may not be very precise, and should be treated with care. Hence to ensure the robustness of the long-run test we also undertake an exclusion test in the cointegration relations found in the last section (see supply relation, Table 2), where we set the $\hat{\beta}$ parameter representing the Q^* variable to zero. We found two significant cointegration vectors in the supply relation, and test the null hypothesis of no market power; $H_0^{cointegration}$: $\hat{\beta}_{1,Q^*} = \hat{\beta}_{2,Q^*} = 0$ against the alternative; $H_{ALT}^{cointegration}$: $\hat{\beta}_{1,Q^*} \neq 0, \hat{\beta}_{2,Q^*} \neq 0$. Using the log-likelihood test of Johansen and Juselius (see section 4), we accept the null hypothesis of no market power clearly at a 5% significance level, obtaining a $\chi^2 = 2.55$. Hence, the conclusion from the error correcting model is strengthened and verified also using the exclusion test; Norway has no market power in the French market for fresh salmon in the long-run.[34]

Table 9

2SLS estimates of the long run parameters in the supply relation in (16), quarterly data from 1981 to 1992 ($k = 4$).

	Parameter	St. Dev./a
ξ_Q	-0.0004	0.0002
ξ_{W1}	-.248	1.507
ξ_{W2}	-.119	0.098
Λ	-0.050	0.044

a/Standard errors are calculated using a linear Taylor approximation, see also Bårdsen (1989).

Finally, we would like to compare the dynamic results with the static model. In Table 10 are presented the results from the estimation of the static supply relation in (18). Also here

[34]The two tests predict quite consistently. The Wald test for $\Lambda = 0$ has a p-value of 0.25, the log-likelihood test of $\hat{\beta}_{1,Q^*} = \hat{\beta}_{2,Q^*} = 0$ with two degrees of freedom has a p-value of 0.28.

the static model fits the data well, but fails to meet the statistical requirement of no autocorrelation. The Q-statistics conclude autocorrelation of higher order; Q(4)= 11.09, Q(8)=22.09 and Q(12)=23.74. The static market power parameter is in the expected interval between -1 and 0, i.e., $\lambda_{static} = -0.019$. Hence, the static result is similar to what we found in the short-run, where $\lambda_0 = -0.025$. Standard inference does not apply in the static model due to the non-stationary variables. Hence, we do not know the accuracy of λ_{static}.

Table 10

2SLS estimates of the static supply relation in (18), quarterly data from 1981 to 1992.

	Parameter	St. Dev.
β_0	24.68	4.41
$D_{t,1}$	-0.06	0.52
$D_{t,2}$	.40	.48
$D_{t,3}$	-0.19	.47
β_Q	-0.0003	0.0001
β_{W1}	-0.52	0.47
β_{W2}	-0.13	0.03
λ_{static}	-0.019	0.013
R^2 between observed and predicted	0.84	

The finding of some market power only in the short-run is in accordance with what Bjørndal and Salvanes (1992) concluded when they summarised the literature on market structure in the salmon market. We use four lags in the supply relation, suggesting that long-run is four quarters, or one year. A possible interpretation is thus that Norway exercises some seasonal market power in the periods when fresh wild caught salmon is unavailable, but that there is not room for any mark-up between years (in the long-run) due to the competition from fringe suppliers such as Scotland and North America. Put differently, if Norway tried to maintain the seasonal mark-up, the competitors supply would increase sufficiently to reduce price to marginal cost. This interpretation reinforces the results of DeVoretz and Salvanes (1993), concluding seasonal mark-up pricing. However, a λ_0 as low as -0.025 interpreted together with a Norwegian market share of more than 70% suggests a very low mark-up, and thus only a very limited possibility of exercising market power. One useful normalisation of the mark-up wedge is the Lerner's measure, $(P-MC)/P=-\lambda/\varepsilon$, where ε is the absolute value of the residual demand elasticity; $\varepsilon=|\varepsilon_{PP}|$ (Buschena and Perloff, 1991). However, with a residual demand elasticity of -1.24, the Lerner measure is even lower than λ_0, predicting a very low mark-up. The low mark-up is in line with what Steen (1994a) found; intertemporal changes in competition matters, but not to the extent that Norway is free to set prices on fresh salmon independently of other salmon products in the long-run.

The adjustment parameter of -0.66 means that whenever marginal cost does not equal perceived marginal revenue, there is not an instant adjustment towards equilibrium, but a gradual adjustment towards it.[35]

To summarise, the French market for salmon is own-price elastic, and fresh salmon is a luxury product. The Norwegian residual demand curve is found to be downward sloping, and Norway seems to have some limited market power in the short-run, but none in the long-run. The time dimension is shown to be important in the analysed market, stressing the necessity of using dynamic models when analysing market structure. The ECM approach proposed in the present chapter is shown to provide a tractable method for dealing with dynamic oligopoly problems, without requiring very detailed data. Further, when comparing the static and the dynamic approach, the static is inadequate, both in terms of statistical and economic predictions. In particular the elasticity predictions in the static demand function seem to be inadequate. Finally, it is shown that the proposed separability tests can help the researcher when undertaking preliminary tests as part of the empirical model specification in these models.

[35]Since we had fewer lags in the demand function, one may ask whether the adjustment speed in the supply relation is a result of the lag length. However, also for $k=2$, we obtain an adjustment parameter in the interval -1 to 0.

4.6. Conclusions

We propose a dynamic reformulation of the Bresnahan-Lau model in an error correcting framework. The most common motivation for using this framework is the statistical importance of accounting for short-run dynamics in the data to provide consistent estimates. Further the framework solves the inference problem when using non-stationary data. The ECM formulation allows for short-run departure from long-run equilibrium in the data. Short-run deviations may be caused by factors such as random shocks, sticky prices, contracts etc. but may also be the result of seasonal shifts in supply and demand. However, by including lagged observations of the endogenous variables the ECM framework incorporate also dynamic factors such as habit formation from the demand side and adjustment costs for the producer. The results suggest that dynamics is important, concluding the static approach to be inadequate for the market in question.

If market power is present the demand function is non-separable in the variables involved in the identification of the market power parameter. This is usually only assumed in the literature. A separability test utilising the multivariate framework of Johansen and Juselius is proposed. The tests conclude non-separability, both in income and the substitute price, and allow us to specify the necessary interaction terms to identify market power.

To illustrate the model, the French market for fresh salmon is analysed. The results suggests the salmon market to be competitive in the long-run, but indicate that Norway has some market power in the short-run. This result is in accordance with conclusions drawn in the literature (Bjørndal & Salvanes, 1992). The demand estimates predict a downward sloping Norwegian residual demand curve, with an own price elasticity of -1.24. The empirical results are overall reasonable, but due to multicollinearity, the estimates show some anomalies. However, the empirical implementation shows that the framework is tractable empirically, and that it provides considerably more information than what the simple static version of the Bresnahan-Lau model provides.

The analysis concluded with four lags in the supply relation. A possible interpretation is thus that Norway exercises some seasonal market power in the periods when fresh wild caught salmon is unavailable, but that there is not room for any mark-up between years (in the long-run) due to the competition from other producers as Scotland and North America. Put differently, if Norway tried to maintain the seasonal mark-up, the competitors supply would increase sufficiently to reduce price to marginal cost. This interpretation reinforces the results of DeVoretz and Salvanes (1993), concluding seasonal monopoly power. However, a λ_0 as low as -0.025 interpreted together with a Norwegian market share of more than 70% suggests a very low mark-up, and thus only a very limited possibility of exercising market power. The low mark-up is in line with what (Steen, 1994a) found; intertemporal changes in competition matters, but not to the extent that Norway is free to set prices on fresh salmon independently of other salmon products in the long-run.

In this analysis we have treated Norway as the dominant firm that set the profit maximisation price which the competitive fringe takes as given. The BL model allows for identifying a mark-up measure, indicating the degree of market power exercised. However, we have neglected possibly dynamic interaction between the fringe and the dominant firm. Buschena and Perloff (1991) model the fringe's supply explicitly, and thereby account for possible interaction. Since our model incorporates dynamics, the interaction between Norway and the fringe may be even more important. Hence, an interesting extension of the present model would be to model the fringe explicitly. However, this requires more data than what we have now.

In section 4 we showed that by assuming the ECM framework we made some restrictions in the dynamics, implicitly assuming myopic behaviour. Hence, an interesting extension will be to make a new model including also leads of the endogenous variable.

The data set runs from 1981 to 1992. After the bankruptcy of the Norwegian fish farmer's sales organisation in November, 1991 the market situation is probably changed. The Norwegian industry structure has changed and resulted in a more horizontally and vertically integrated industry. There is, however, no alternative organisation to replace the sales organisation, which implies that there is probably a more competitive industry today.

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Appendix 4A - Data description and variable definition

Price of Norwegian fresh salmon in France *(P),* Norwegian fresh salmon quantity sold in France *(Q)*, and the price of North American frozen salmon in France *(Z)* are from quarterly import data from the EU trade statistics, EUROSTAT, from 1981 to 1992 (*n*=48). The data is extracted from EUROSTAT's COMEXT database Chapter 3 *'Fish and crustaceans, molluscs and other aquatic invertebrates'*. Prior to 1988, fresh salmon was registered as one aggregated product, No. 030103 (EUROSTAT's HS-nomenclature), 'Fresh or chilled salmon'. In 1988 it was dissaggregated into No. 03021200, 'Fresh or chilled salmon' and No. 03041013, 'Fresh or chilled fillets of salmon'. In order to ensure compatibility from 1988 to 1992 these two groups are aggregated. A parallel harmonisation is done for frozen salmon. Prior to 1988 No. 030104 is used. From 1988 to 1992 No. 03031000, No. 03032200 and No. 03042013 are aggregated. The data was provided by EUROSTAT, and was prepared for the present purpose at the Norwegian College of Fishery Science, University of Tromsø, Tromsø, Norway. Prices are FOB, in ECU, and were deflated using the French consumer price index using 1985 as the base year. The consumer price index is from IMF's International Financial Statistics. Quantity units are in tonnes.

The income variable *(Y)* used is quarterly French private consumption, deflated using the French consumer price index. The private consumption figures are from IMF's International Financial Statistics.

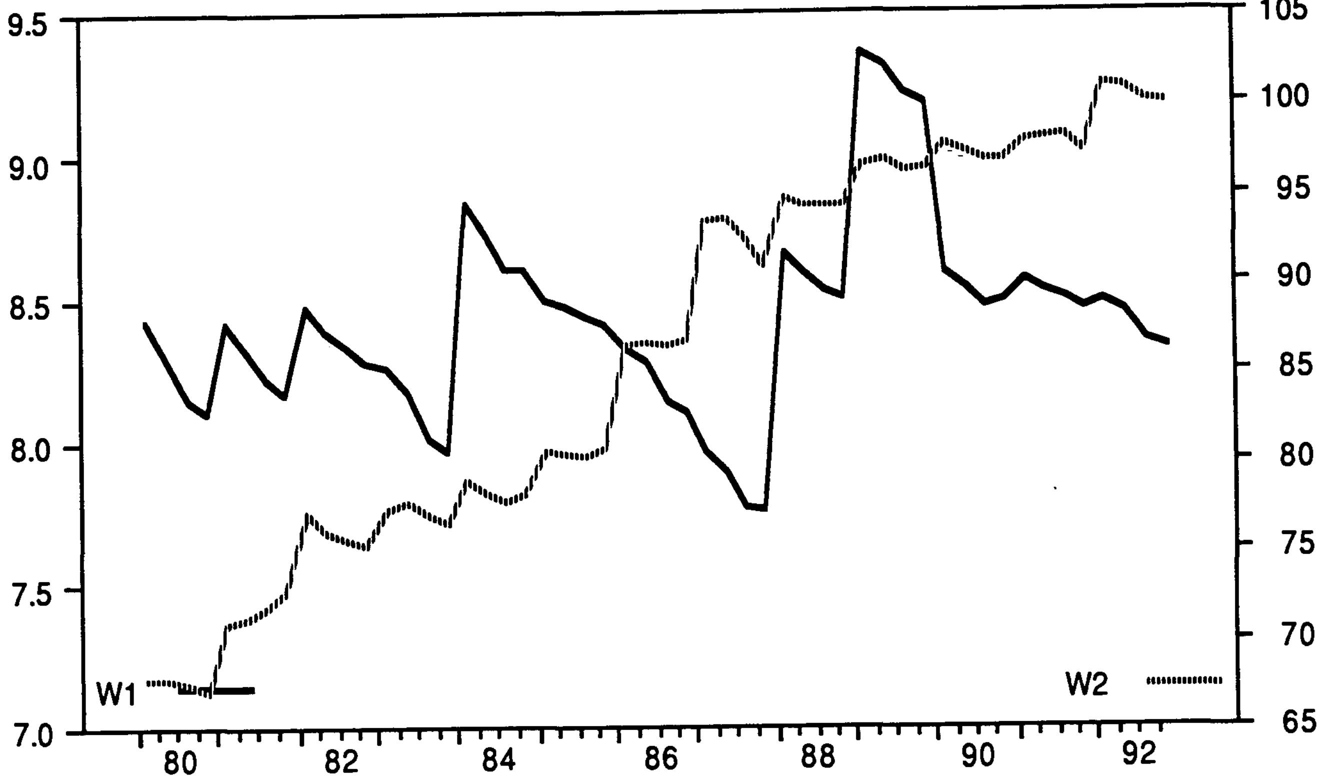
Feed price *(W1)* is yearly feed prices from one of the major Norwegian feed producers; *Skretting*, deflated using the Norwegian consumer price index.

The wage index *(W2)* is a quarterly Laspeyres index based on two labour price series; Norwegian quarterly real unit labour costs in manufacturing, and the yearly average wage per hour in salmon farming. The latter was deflated using the quarterly Norwegian consumer price index prior to the estimation of the Laspeyres index. The two wage series were given equal weights in the Laspeyres index. The Norwegian consumer price index and real unit labour costs in manufacturing are from IMF's International Financial Statistics. The average salmon farming wage is from the Norwegian Directorate of Fishery's yearly profitability studies. In

Figure A1 the two series W1 and W2 are shown.

Figure A1

Norwegian quarterly feed price (*W1*) and wage index (*W2*) in salmon farming in the period from 1981 to 1992.



Statistical properties for all the variables, including the interaction terms *PZ* and *PY* are presented in Table A1.

Table A1

Statistical properties of main variables (n=48).

		Mean	St.Dev.	Minimum	Maximum
Q	fresh salmon quantity	3131.4	2959	183	11141
p	fresh salmon price	7.92	2.35	4.32	12.53
Z	frozen salmon price	6.13	2.01	2.71	9.53
Y	private consumption	3935.3	469.61	2850.2	4587.6
PZ	Interaction term price/ substitute price	52.32	27.95	11.69	103.52
PY	Interaction term price/ private consumption	30273	6760	19586	47369
W1	feed price	8.44	0.35	7.76	9.36
W2	wage index	87.44	9.93	70.94	101.09

Appendix 4B - The relationship between the Autoregressive Distributed Lag (ADL) model and the Error Correction (ECM) formulation.

Here it will be shown how the ECM formulation relates to the ADL model for the Bresnahan-Lau model used here. In particular, we show that the parameters representing the stationary long-run solution of the ADL model, and its parameters are the same as the long-run parameters found directly in the ECM formulation.

The Demand Function

The demand function in (3) as represented by the ADL form with one lag and without an intercept term is;

$$\text{(B1)} \quad Q_t = \alpha_{P0}P_t + \alpha_{P1}P_{t-1} + \alpha_{Z0}Z_t + \alpha_{Z1}Z_{t-1} + \alpha_{PZ0}PZ_t + \alpha_{PZ1}PZ_{t-1} + \alpha_{Q1}Q_{t-1} + \varepsilon_t.$$

The short-run parameters are the coefficients on the contemporaneous variables, i.e., α_{P0}, α_{Z0} and α_{PZ0}. The long-run stationary solution is found when $Q_t = Q_{t-1}$, $P_t = P_{t-1}$, $Z_t = Z_{t-1}$ and $PZ_t = PZ_{t-1}$. The ADL demand model in (B1) then becomes;

$$\text{(B2)} \quad Q = \left[\frac{\alpha_{P0} + \alpha_{P1}}{1 - \alpha_{Q1}}\right]P + \left[\frac{\alpha_{Z0} + \alpha_{Z1}}{1 - \alpha_{Q1}}\right]Z + \left[\frac{\alpha_{PZ0} + \alpha_{PZ1}}{1 - \alpha_{Q1}}\right]PZ.$$

The long-run solution is characterised by three long-run parameters, represented by the three brackets in (B2). These are equivalent to the long-run parameters θ_j in the ECM representation in equation (9). To see this add and delete Q_{t-1}, $\alpha_{P0}P_{t-1}$, $\alpha_{Z0}Z_{t-1}$ and $\alpha_{PZ0}PZ_{t-1}$ of the right hand side of (B1);

$$\begin{aligned} Q_t = {} & \alpha_{P0}P_t + \alpha_{P1}P_{t-1} + \alpha_{Z0}Z_t + \alpha_{Z1}Z_{t-1} + \alpha_{PZ0}PZ_t + \alpha_{PZ1}PZ_{t-1} + \alpha_{Q1}Q_{t-1} \\ & + \alpha_{P0}P_{t-1} - \alpha_{P0}P_{t-1} + \alpha_{Z0}Z_{t-1} - \alpha_{Z0}Z_{t-1} + \alpha_{PZ0}PZ_{t-1} - \alpha_{PZ0}PZ_{t-1} + Q_{t-1} - Q_{t-1} + \varepsilon_t, \end{aligned}$$

then rearrange;

$$Q_t - Q_{t-1} = (\alpha_{P0}P_t - \alpha_{P0}P_{t-1}) + (\alpha_{P0}P_{t-1} + \alpha_{P1}P_{t-1}) + (\alpha_{Z0}Z_t - \alpha_{Z0}Z_{t-1}) + (\alpha_{Z0}Z_{t-1} + \alpha_{Z1}Z_{t-1})$$
$$+ (\alpha_{PZ0}PZ_t - \alpha_{PZ0}PZ_{t-1}) + (\alpha_{PZ0}PZ_{t-1} + \alpha_{PZ1}PZ_{t-1}) + (\alpha_{Q1}Q_{t-1} - Q_{t-1}) + \varepsilon_t,$$

and use the difference operator;

$$\Delta Q_t = \alpha_{P0}\Delta P_t + (\alpha_{P0} + \alpha_{P1})P_{t-1} + \alpha_{Z0}\Delta Z_t + (\alpha_{Z0} + \alpha_{Z1})Z_{t-1}$$
$$+ \alpha_{PZ0}\Delta PZ_t + (\alpha_{PZ0} + \alpha_{PZ1})PZ_{t-1} + (\alpha_{Q1} - 1)Q_{t-1} + \varepsilon_t.$$

Finally, we can formulate the equation as an ECM representation;

(B1')
$$\Delta Q_t = \alpha_{P0}\Delta P_t + \alpha_{Z0}\Delta Z_t + \alpha_{PZ0}\Delta PZ_t$$
$$+ (1 - \alpha_{Q1})\left\{Q_{t-1} - \left[\frac{\alpha_{P0} + \alpha_{P1}}{1 - \alpha_{Q1}}\right]P_{t-1} - \left[\frac{\alpha_{Z0} + \alpha_{Z1}}{1 - \alpha_{Q1}}\right]Z_{t-1} - \left[\frac{\alpha_{PZ0} + \alpha_{PZ1}}{1 - \alpha_{Q1}}\right]PZ_{t-1}\right\} + \varepsilon_t$$

Including an intercept term, and for k=1, equation (B1') is the same as the demand function in (8). The short-run parameters are the same as in the ADL model, but are now found as the coefficients on the contemporaneous differenced variables (α_{P0}, α_{Z0} and α_{PZ0}). The adjustment parameter γ^* in (8) corresponds to $\gamma^* = 1 - \alpha_{Q1}$ in (B1'), and α_j^* in (9) correspond to $\alpha_j^* = \alpha_{j0} + \alpha_{j1}$, for j=P,Z,PZ. The long-run parameters θ_j are thus the terms in the brackets, i.e., $\theta_j = (\alpha_{j0} + \alpha_{j1})/(1 - \alpha_{Q1}) = \alpha_j^*/\gamma^*$. Hence, the long-run parameters in the ECM representation in (B1') corresponds to the long-run parameters in (B2). Further, since the estimated γ^* and α_j^* are made of a combination of all the period's αs, they measure the cumulative effect of all the periods included in the model (defined by the number of lags) i.e. with k=1, they measure the cumulative effect over two periods.

<u>*The Supply Relation*</u>

The variable used in the identification of the market power parameter, Q^*, is calculated using the long-run parameters in (B1') using equation (11);

(B3) $$Q^* = Q_t \Big/ (\theta_P + \theta_{PZ} Z_t) = Q_t \Big/ \left(\tfrac{\alpha_{P0}+\alpha_{P1}}{1-\alpha_{Q1}} + \tfrac{\alpha_{PZ0}+\alpha_{PZ1}}{1-\alpha_{Q1}} Z_t\right)$$

The supply relation in (5) parameterised by an ADL form with one lag and without an intercept term is then;

(B4) $$P_t = \beta_{Q0} Q_t + \beta_{Q1} Q_{t-1} + \beta_{W0} W_t + \beta_{W1} W_{t-1} + \lambda_0 Q_t^* + \lambda_1 Q_{t-1}^* + \beta_{P1} P_{t-1} + \eta_t.$$

The short-run parameters are the coefficients of the contemporaneous variables, i.e., β_{Q0}, β_{W0} and λ_0. The long-run stationary solution is found when $P_t = P_{t-1}$, $Q_t = Q_{t-1}$, $W_t = W_{t-1}$, and $Q_t^* = Q_{t-1}^*$. The ADL supply relation in (B4) then becomes;

(B5) $$P = \left[\frac{\beta_{Q0} + \beta_{Q1}}{1 - \beta_{P1}}\right] Q + \left[\frac{\beta_{W0} + \beta_{W1}}{1 - \beta_{P1}}\right] W + \left[\frac{\lambda_{Q^*0} + \lambda_{Q^*1}}{1 - \beta_{P1}}\right] Q^*.$$

The long-run solution is also here characterised by three long-run parameters, represented by the three brackets in (B5). These are equivalent to the long-run parameters ξ_Q, ξ_W and Λ in equation (12). To see this, add and delete P_{t-1}, $\beta_{Q0} Q_{t-1}$, $\beta_{W0} W_{t-1}$ and $\lambda_{Q^*0} Q_{t-1}^*$ at the right hand side of (B4), and then rearrange in the same fashion as we did with the demand function. The supply relation in (B4) in ECM then becomes;

(B4') $$\begin{aligned} \Delta P_t &= \beta_{Q0} \Delta Q_t + \beta_{W0} \Delta W_t + \lambda_0 \Delta Q^*_t \\ &+ (1 - \beta_{P1}) \left\{ P_{t-1} - \left[\frac{\beta_{Q0} + \beta_{Q1}}{1 - \beta_{P1}}\right] Q_{t-1} - \left[\frac{\beta_{W0} + \beta_{W1}}{1 - \beta_{P1}}\right] W_{t-1} - \left[\frac{\lambda_0 + \lambda_1}{1 - \beta_{P1}}\right] Q_{t-1}^* \right\} + \eta_t. \end{aligned}$$

Including an intercept term, and for k=1, equation (B4') is the same as the supply relation in

(10). The short-run parameters are the same as in the ADL model, but are now found as the coefficients of the contemporaneous differenced variables (β_{Q0}, β_{W0} and λ_0). The adjustment parameter ψ^* in (8) corresponds to $\psi^* = 1 - \beta_{P1}$ in (B4'). ξ_Q, ξ_W and Λ in (12) correspond to the long-run parameters in the brackets in (B4'), e.g., $\xi_Q = (\beta_{Q0} + \beta_{Q1})/(1 - \beta_{P1}) = \beta_Q^*/\psi^*$. Hence, the long-run parameters in the ECM formulation in (B4') corresponds to the long-run parameters in (B5). Finally, since the estimated ψ^*, β_Q^*, β_W^* and λ^* are combinations of all the period's β's and λ's, they measure the cumulative effect of all the periods included in the model.

—Chapter 5—

Summary

Summary

In chapter one a survey of the EU salmon market is provided. The supply side of salmon in the EU is dominated by a few large countries, Norway, Scotland, the US and Canada. In particular, the market for fresh salmon is concentrated, and Norway and Scotland account for 80 to 90% of the market.

Central participants in this market have regarded Norway and Scotland as market leaders with an ability to influence prices and exercise market power in the EU market. The producer associations in Norway and Scotland were found guilty for constituting an agreement on price co-ordination in EU by the EU Commission in 1992.

The literature on market structure is ambiguous, though the conclusion is that there is a competitive market in the long run. However, the market characteristics and the literature provide arguments which indicate that Norway may have had some oligopolistic market power in the short run. Further, due to the intertemporal restrictions in the North American supply, models allowing for intertemporal price discrimination may be appropriate in the EU salmon market.

With the exception of DeVoretz and Salvanes (1993), no one has tried to model and test for market structure explicitly using new empirical industrial organisation models in this industry. This leaves parts of the empirical question about market structure open for future research, and defines the starting point for the analyses undertaken in this dissertation.

Market Delineation

In chapter two we propose the use of Johansen and Juselius' multivariate cointegration methodology as a market delineation tool. The importance of accounting for stochastic seasonality when applying cointegration analysis with seasonal data is also addressed. When testing for long-run relationships one is basically interested in the long-run zero frequency processes. However, stochastic seasonality may act as noise in the variables, making the cointegration methodology less able to reveal possible long-run relationship. Here, we exploit Beaulieu & Miron's (1993) test for seasonal integration. We test for seasonal integration, and based on the results appropriate filters are calculated to extract possible seasonal unit roots, leaving only the long-run zero frequency processes. Then the new filtered series are used as inputs in the cointegration tests.

We focuse both on the product and geographic space. The tests provide evidence for fresh, frozen and smoked salmon to be in the same market. The geographic tests are more ambiguous, suggesting two different geographic markets for frozen salmon in the EU; one single market in France, and the rest of the EU as an aggregated group. The market for fresh salmon is found to be more integrated, i.e., one EU market for fresh salmon. The six countries/areas included represent between 86 and 97% of the EU market for salmon in the analysed period. Hence, the conclusions should be applicable to all of the EU.

The way seasonality is treated in this analysis is new, both in the literature on market delineation and the more general literature on cointegration and seasonality. Further, empirically our analysis provided support for this seasonality approach. Typically, the cointegration tests provide clearer test statistics when stochastic seasonality is accounted for.

Aggregation level is found to be important when testing for seasonal unit-roots. At the aggregated EU level we find no seasonal unit-roots for any of the series, but at the country level several series are found to have seasonal unit-roots. Thus, when using micro-data it is even more important to account for stochastic seasonality than in macro analysis where this methodology has been used earlier.

Using tests for market delineation, chapter two focuses on the importance of intertemporal changes in the degree of competition. In a competitive market with no barriers to arbitrage, one would expect the prices of close substitutes to follow some long-run relationship. Competition acts as a disciplinary device forcing prices to marginal cost, and arbitrage forces prices of close substitutes sold in the same market to uniformity. However, if there are periods in which the degree of competition in the market is reduced due to biological constraints on supply, the price interdependencies may be weaker in these periods. We show that by dividing the price series into two parts, a low-competition data set and a high-competition data set, and by undertaking multivariate cointegration tests on both data sets and comparing the results from the two regimes, one may test for the significance of the changes in competition.

The analysis provides some support for the hypothesis that reduced competition negatively affects the stability of the cointegration relations, suggesting a lower interdependence of prices during the low-competition periods. However, the multivariate tests show cointegration in both the high-competition and the low-competition periods, and the exclusion tests do not allow one to exclude fresh salmon from the long-run relationships. Hence, the interdependencies between fresh, frozen and smoked salmon are too strong to allow prices of fresh salmon to move independently. Thus, changes in intertemporal competition matter, but not to the extent that Norway is free to set price on fresh salmon independently of the prices for frozen and smoked salmon even in the low-competition periods. These findings weaken the argument that Norway may have seasonal monopoly power and thus may have exercised intertemporal price discrimination in the market for fresh salmon in the periods in which wild-caught salmon was unavailable.

The findings in this chapter correspond to the results found in chapter 2, where fresh, frozen and smoked salmon were found to belong to the same market. The present analysis also accounts for intertemporal changes in competition. Thus, the results provided here strengthen the basis for concluding that there is an integrated market for fresh, frozen and smoked salmon.

Recently, the relationship between the cointegration approach to market delineation and the demand structure among different products in terms of degree of substitutability is analysed (Asche, Salvanes, & Steen, 1994). In this study cointegration tests together with estimation of a dynamic system of demand equations are undertaken for three high quality sea food products in the EU. The results are encouraging as the results from the two approaches are not only compatible, but also complimentary in the sense that they provide more information together than separately.

Konishi & Granger (1992) have shown that it is possibly to use the cointegration framework to test not only for cointegration in a system of variables, but also to test for when it is appropriate to consider only subsystems, i.e., separation in cointegrated systems. The test framework is based on the same technology as the one used in chapter 2 and 3; the Johansen & Juselius (1990) multivariate cointegration test. This may have interesting applications also when testing for market delineation. For instance, consider two regions and four substitute commodities, whereof two are sold in each region. Using the new separation test proposed by Konishi & Granger, one is able to distinguish between hypotheses as; *(i)* Four separate markets, *(ii)* one total market consisting of four commodities, and *(iii)* two separate regional sub-markets consisting of two commodities. Hence, separation tests in cointegrated systems may be an even stronger market delineation tool than the standard multivariate Johansen & Juselius test, and should be considered in future work in this area.

Market Structure

Based on the information about market boundaries and the importance of seasonal shifts in supply and demand, chapter four proposes a dynamic reformulation of the oligopoly model of Bresnahan (1982) and Lau (1982) in an error correction framework. The motivation for using this framework is twofold. First, the model accounts for short run dynamics in the data, and solves the inference problem when using non-stationary data. The ECM formulation allows for short run departure from long run equilibrium in the data. Short run deviations may be caused by factors such as random shocks, sticky prices, contracts etc. but may also be the result of seasonal shifts in supply and demand. Secondly, by including lagged observations of the endogenous variables the ECM framework incorporates also dynamic factors such as habit formation from the demand side and adjustment costs for the producer. The results suggest that dynamics is important, concluding the static approach to be inadequate for the market in question.

If market power is present the demand function is non-separable in the variables involved in the identification of the market power parameter. This is usually only assumed in the literature. A separability test utilising the multivariate framework of Johansen and Juselius (1990) is proposed. The tests conclude non-separability, both in income and the substitute price, and allow us to specify the necessary interaction terms to identify market power.

To illustrate the model, the French market for fresh salmon is analysed. The results suggests the salmon market to be competitive in the long run, but indicate that Norway has some market power in the short run. This result is in accordance with conclusions drawn in the literature (Bjørndal & Salvanes, 1992). The demand estimates predict a downward sloping Norwegian residual demand curve, with an own-price elasticity of -1.24. The empirical results are overall reasonable, but due to multicollinearity, the estimates show some anomalies. However, the empirical implementation shows that the framework is tractable empirically, and that it provides considerably more information than what the simple static version of the Bresnahan-Lau model provides.

The analysis indicates four lags in the supply relation. A possible interpretation is thus that Norway exercises some seasonal market power in the periods when fresh wild caught salmon is unavailable, but that there is not room for any mark-up between years (in the long run) due to the competition from other producers as Scotland and North America. Put differently, if Norway tried to maintain the seasonal mark-up, the competitors supply would increase sufficiently to reduce price to marginal cost. This interpretation reinforces the results of DeVoretz and Salvanes (1993), concluding seasonal monopoly power. However, with a market power measure, λ_0 as low as -0.025 interpreted together with a Norwegian market share of more than 70% suggests a very low mark-up, and thus only a very limited possibility of exercising market power. The low mark-up is in line with what we found in chapter three: intertemporal changes in competition matters, but not to the extent that Norway is free to set prices on fresh salmon independently of other salmon products in the long run.

In chapter four we treate Norway as the dominant firm that set the profit maximisation price which the competitive fringe takes as given. The BL model allows for identifying a mark-up measure, indicating the degree of market power exercised. However, we have neglected possibly dynamic interaction between the fringe and the dominant firm. Buschena and Perloff (1991) model the fringe's supply explicitly, and thereby account for possible interaction. Since our model incorporates dynamics, the interaction between Norway and the fringe may be even more important. Hence, an interesting extension of the present model would be to model the fringe explicitly. However, this requires more data than what we have now.

In section 4.4. we showed that by assuming the ECM framework we made some restrictions in the dynamics, implicitly assuming myopic behaviour. Hence, an interesting extension will be to make a new model without this restriction imposed. This may be done by using a dynamic framework where also leads of the endogenous variable are included.

In chapter four we learned the necessity of a proper empirical model specification. For instance, how to account for positive shifts in demand. In addition to the price variable, we included income as a shift variable. However, this variable increases by only 60% during the sample period. The quantity imorted to the EU in 1992 was 22 times higher than the quantity imported in 1981. Hence, the outward shifts in demand cannot be fully explained by income. Due to changes in distribution channels, penetration of new market segments and increased concern about nutrition, the demand has shifted outward. These factors are not modelled, and is thus only captured through the income variable. Hence, the estimated income elasticity captures more than changes in income and may therefore be too high. This is something our model has in common with most of the demand literature in this market.[1] Future demand studies will probably benefit from modelling also these other shift variables explicitly in this industry.

An interesting extension of the analysis in chapter four is to model the supply side more explicitly. The production of salmon is a biological determined process. This may have implications for how to model the supply side (Tomek & Robinson, 1990). Due to growth-out periods, the production decision is made under uncertainty about future price and demand. For instance, empirical studies in farming show that both the level and the slope of the supply curve

[1] An exception is Bjørndal, Salvanes & Andreassen (1992) that included advertising in their model.

can be influenced by uncertainty in prices (Hurt & Garcia, 1982; Meyer & Tomek, 1987; Traill, 1978). Further, since salmon farming is a relatively young industry, there may be a learning curve effect present that may be modelled also empirically.

The data set used throughout the dissertation runs from 1981 to 1992. After the bankruptcy of the Norwegian fish farmer's sales organisation in November, 1991 the market situation is probably changed. The Norwegian industry structure has changed and resulted in a more horizontally and vertically integrated industry. There is however, no alternative organisation to replace the sales organisation, which implies that there is probably a more competitive industry today.

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