Marine Resource Economics, Volume 17, pp. 225–238
Printed in the U.S.A. All rights reserved

0738-1360/00 $3.00 + .00

Allocation of Fish Between Markets and Product Forms

FRANK ASCHE
Stavanger University College

RÖGNVALDUR HANNESSON
Norwegian School of Economics and Business Administration

Abstract *In this paper, we investigate the suppliers' allocation decisions between different product forms and markets using supply equations derived from a translog revenue function. This is of interest based on the hypothesis that fish processors and importers respond to changes in relative prices, diverting more fish into products or to markets where the price has risen. This can also at least partially explain the strong degree of correlation between prices of different product forms and markets that is observed in many seafood markets. An empirical analysis is carried out for cod for three main producers, Canada, Iceland, and Norway. The supply of cod exhibits substantial variation, and it is processed into a number of product forms. How the landings are allocated between product forms is then of substantial interest in itself, but also with respect to the influence of new species in the whitefish market, like pollock.*

Key words Cod, revenue function, seafood, supply response, value chain.

JEL Classification Codes Q22, Q21, F16.

Introduction

Several recent studies have indicated that there is a global market for whitefish, consisting of all species and product forms (Gordon and Hannesson 1996; Asche and Hannesson 1997; Asche, Gordon, and Hannesson 2002). However, salmon and other species of high-valued fish and seafood, as well as meat products, do not seem to belong to this market (Gordon, Salvanes, and Atkins 1993; Asche and Hannesson 1997). Presumably, it is responsiveness on behalf of producers and consumers of cod and other whitefish products that makes their prices follow a similar pattern over time. If the price of one product deviates from the general pattern of prices, consumers will desert that product, while producers will increase its production or vice versa.[1]

Frank Asche is a professor at Stavanger University College and Centre for Fisheries Economics, Norwegian School of Economics and Business Administration, Box 8002, N-4068 Stavanger, Norway, email: Frank.Asche@tn.his.no. Rögnvaldur Hannesson is a professor in the Centre for Fisheries Economics, Norwegian School of Economics and Business Administration, Helleveien 30, N-5045 Bergen, Norway, email: Rognvaldur.Hannesson@nhh.no. The authors wish to acknowledge the financial support of the European Commission (FAIR Contract nos. CT95-0892 and CT99-01346) and the Norwegian Research Council. The comments of two anonymous referees were helpful in improving the final version of the paper. The views expressed herein are those of the authors and are not to be attributed to the European Commission or the Norwegian Research Council.

[1] Relationships between prices are observed for many products and seafood markets. Some recent studies not related to the whitefish market include Bose and McIlgrom (1996); Asche, Bremnes, and Wessells (1999); Jaffry *et al.* (2000); Asche (2001).

In this paper we investigate supply-side responsiveness to price changes by estimating a system of supply equations. The ex-vessel supply of fish has been investigated in a number of studies (Squires 1987a,b; Kirkley and Strand 1988; Squires and Kirkley 1991; Salvanes and Steen 1994; Salvanes and Squires 1995). However, with the exception of Bockstael (1977) and Gordon, Hannesson, and Bibb (1993), little attention has been given to the allocation of landed fish between different markets and product forms.[2] We focus on products derived from cod in three countries, Norway, Canada, and Iceland. Cod is an important source of product in the whitefish market, and the three aforementioned countries are, or used to be, the most important sources of cod in international trade.

The response to price changes in the markets for final products will take place at two different levels. First, first-hand sales to various end users will be affected by prices in the final markets to the extent changes in prices in these markets filter through to first-hand prices.[3] Improved profitability in the production of *e.g.*, frozen fillets will, one would presume, entice producers of these to outbid other processors in the first-hand market and thus grab a larger share of the total quantity of fish on offer. The extent to which this will happen will, however, depend on the available production capacity. Some types of processing are likely to be more elastic than others. For example, we would expect exports of fresh fish to be more responsive to price changes than frozen and cured fish, as the latter require more elaborate processing facilities. Also, we would expect the production of salted fish to be more responsive than the production of frozen fillets, as the latter requires more elaborate facilities with tighter limits on the capacity of production.

The second stage at which responses to changes in product prices occur is at the level of processing. Processors of frozen fillets, for example, have a choice of producing fillets for different national markets (the United States versus the United Kingdom and markets on the continent of Europe). All these different markets have their own idiosyncratic requirements, even if basically the same product is being offered, frozen chunks of fish wrapped in paper or cellophane. Different kinds of products may also be offered in the same national market; *i.e.*, frozen fillets and frozen blocks sold to the US. The prices of these may change in different directions, to which producers may be expected to respond. In this paper, we examine the responsiveness in the production of frozen cod fillets in the three aforementioned countries to changes in the import prices (unit values) in the markets in the US, the UK, France, and Germany.

Ideally, a model of the allocation mechanism would look at the whole range of products and markets and estimate supply response equations for each of these. The data at our disposal did not allow this. First, what we instead can do is look at the allocation of raw fish between broad categories (fresh, frozen, and salted).[4] This ought to tell us something of interest about the supply responsiveness of the processing industry for different products. Second, we look more closely at the allocation of frozen fillets between markets, as this is one of the most important groups of products produced from cod and other whitefish. This analysis proceeds as if the total supply of fillets is predetermined independently of prices and looks at the allocation of fillets between different national markets. By doing this, we assume that different suppliers are price takers and that the decision about in which market to sell the fish is independent of how much to produce of each product form. These as-

---

[2] Mazany, Roy, and Schrank (1996) estimate supply functions for Canadian frozen cod fillets to the US, and Toft and Bjørndal (1997) provide a productivity analysis of the Norwegian processing sector for whitefish.

[3] Asche *et al.* (2002) indicate that this is the case to a very large extent in the Norwegian value chains, as the price transmission elasticities are high.

[4] Alternatively, one can model a specific value chain like Bockstael (1977), and treat the world market as given.

sumptions will be discussed in the next section. Despite its limitations, this approach ought to provide insights into the responsiveness of suppliers engaged in this type of production.

We first investigate how Icelandic and Norwegian cod landings are allocated between different product forms (salting, freezing, and exports of fresh fish). We were unable to include Canada, as we did not have the relevant data. Then, we will look at how the supply of frozen cod fillets from the three main suppliers, Canada, Iceland, and Norway, is allocated between the main markets, France, Germany, the UK, and the US. However, we start with a description of the method used and the data sets.

Supply Relationships

We will not be particularly concerned with how the price of whitefish is determined. Given that there seems to be a global market for all types and product forms of whitefish, this gives us important information about the price determination process. Most whitefish is caught in industrialized countries in fisheries that are regulated by a Total Allowable Catch (TAC), and for most of these fisheries there are often numerous additional regulations like limited entry, effort controls, *etc.* There is also large overcapacity in the fleets, and the fishermen are often heavily subsidized (Milazzo 1998; Hatcher and Robinson 1999). Given all the regulations and interventions in the production process, price is not likely to play a major role when determining total supply. Hence, quantity can be treated as exogenous, and the market price will be determined by aggregate demand, given the supplied quantity.[5] Since there are a number of suppliers of whitefish, no one has seriously raised the issue that anyone has market power in the whitefish market. We will, therefore, proceed under the assumption that all agents in the whitefish market are price takers.

When assuming that the price of the finished product is determined on the world market and can be treated as exogenous, the different suppliers' optimization problem becomes one of determining how large shares of the landings should be allocated to the production of different product forms and markets. The mechanism by which this occurs can, for the countries we are looking at, be assumed to be market driven, as the processing industry consists of private enterprises. How this mechanism exactly works is unclear. Some processing companies, particularly in Canada and Iceland, are vertically integrated and will presumably decide their allocation of raw fish between products and markets on the basis of the prices of the final products. Other firms, particularly in Norway, specialize in fishing and have weak or no links with the processing industry. These firms typically sell to those who offer the highest prices, either through organized fish auctions or bilateral contracts. The prices offered by the processing companies will presumably be linked to prices of final products.

The Revenue Function

To investigate the supply relationships, we estimate the supply equations derived from a translog revenue function.[6] This approach is quite common in fisheries and other industries where it is reasonable to treat the input variables as given, due to

[5] This follows from Thurman (1986), who discusses the issue of simultaneity in demand in general. It might also be of interest to note that fisheries are among the few cases where inverse demand functions are regarded as plausible alternatives in the economics literature, due to the nature of supply (Gorman 1959).

[6] For a discussion of revenue functions, see McFadden (1978). The translog functional form is due to Christensen, Jorgensen, and Lau (1973).

biological or other constraints (Kirkley and Strand 1988; Gordon 1989; Squires and Kirkley 1991; Gordon, Hannesson and Bibb 1993; Salvanes and Steen 1994). Since our analyses are at the processing level, we follow Gordon, Hannesson and Bibb by using total quantity available to the processors at a given level in the value chain as the exogenous factor.[7] The problem of the processors then becomes how to allocate available quantity to different product forms/markets. The available quantity will depend on which stage in the decision process one is investigating.

A translog revenue function is given as:

$$R(p,x) = a_0 + \sum_i b_i \ln p_i + \sum_i \sum_j c_{ij} \ln p_i \ln p_j + d_0 \ln x + \sum_i d_i \ln p_i \ln x, \qquad (1)$$

where p_i is the price of the ith product or the price in the ith market, and x is the level(s) of the input factor(s) (in our case the quantity to be allocated).[8] The share equation for the ith good (the ith market) is:

$$S_i = b_i + \sum_j c_{ij} \ln p_j + d_i \ln x. \qquad (2)$$

As the revenue shares sum to one, the system given in equation (2) is singular. To avoid this problem, one equation is deleted before estimation. The results are invariant to which equation is deleted, and the parameters in the deleted equation can be recovered by the adding up condition. The adding up, homogeneity, and symmetry restrictions implied by economic theory are as follows:

$$\text{Adding up:} \quad \sum_i b_i = 1, \quad \sum_i c_{ij} = 0, \quad \sum_i d_i = 0$$

$$\text{Homogeneity:} \quad \sum_j c_{ij} = 0$$

$$\text{Symmetry:} \quad c_{ij} = c_{ji}.$$

The homogeneity and symmetry restrictions are imposed before estimation to make the estimated supply equations conformable with economic theory. Each system of equations is then estimated as a system of Seemingly Unrelated Regressions.

The own-price supply elasticity is given as:

$$\varepsilon_{ii} = \frac{c_{ii}}{S_i} + S_j - 1 \qquad (3)$$

and the cross-price elasticities are given as:

$$\varepsilon_{ij} = \frac{c_{ij}}{S_i} + S_j, \qquad (4)$$

---

[7] The cost share of the fish is very high for the processing industry, as shown in a study for Norway by Toft and Bjørndal (1997). Moreover, tests indicate that capital and labor can be treated as fixed factors (Asche *et al.*, 2002). Hence, it is not unreasonable to represent the processors' problem as how to allocate the available supply of fish between product forms and markets.

[8] In contrast to Gordon, Hannesson, and Bibb (1993), we do not assume constant returns to scale.

where $i \neq j$. Negative cross-price elasticities indicate substitutes, while positive cross-price elasticities indicate complements.

Weak Separability

We are modeling two decisions independently which, in principle, can be made simultaneously. First, the decision of which product form to produce and second, in which market to sell the products. When allocating product between different markets, this decision is then conditioned on the decision to produce a given quantity of this product form at the level above. Hence, the decision to produce a given quantity of frozen fillets feeds into the allocation decision of where to sell the frozen fillets through the total quantity variable at this level. However, reallocation of quantities between markets does not affect the total quantity of frozen fillets produced.

By investigating these decisions independently, we assume that the product forms are weakly separable from each other.[9] In most applied analyses, several separability assumptions are made partly to give the addressed problems manageable dimensions and partly because of data limitations.[10] Our weak separability assumption is implicitly made also by Gordon, Hannesson, and Bibb (1993), and is reasonable given the structure of the whitefish market. The quantity variable, x, will be different, depending on which stage in the decision process one is looking at, as it is the total quantity of cod that is available at the given stage. Please also note that the estimated systems and elasticities have different interpretations depending on which allocation decision is investigated.

Data

The data used in this study are monthly for the period January 1980 to December 1996. As noted above, the analysis will be carried out in two steps. The analysis of allocation of frozen cod fillets between markets will be carried out for supply from Canada, Iceland, and Norway. We restrict ourselves to looking only at the frozen fillets category in allocation between markets. This is mainly because frozen fillets are the most widely traded product. The quantities of other product forms are either very small (fresh, dried) or mainly exported to a specific geographical region (salted cod mainly goes to Brazil, Portugal, and Spain, and dried cod is mainly consumed in Italy).

Data on imports of frozen cod fillets from Canada, Iceland, and Norway to France, Germany, and the UK were obtained from Eurostat, through the Norwegian Seafood Export Council. Data on imports from Canada, Iceland, and Norway to the US were obtained from the National Marine Fisheries Service, Silver Spring, Maryland. The US import statistics are somewhat more detailed than the European and allow us to separate frozen block fillets from frozen fillets. Since most frozen cod is consumed in either Europe or the US, these data should take us a long way in covering the global market. Russia has become an increasingly important exporter since the early 1990s, but as a very substantial share of the processing takes part in Norway, the data should also cover most of the world's exports.[11]

---

[9] See Chambers (1988) for a discussion of separability in the context of the firm.

[10] See Squires (1987c) for a discussion of some of the most common separability assumptions made in analyses of fisheries.

[11] According to FAO (2000), total landings of cod were 1.3 million tons in 1996. Canada, Iceland, and Norway landed 43% and Russia 23%. Most of the remaining catches were landed by different EU countries, with Denmark being the largest with about 6% of total landings.

Lack of data prevents us from modeling the allocation of landings between product forms for Canada, and hence, this analysis is only carried out for Iceland and Norway. Data on allocation of raw fish to different uses in Norway were obtained from the Norwegian Directorate of Fisheries. These data cover the area of "Norges Råfisklag," approximately the area north of and including the town of Kristiansund. This corresponds to about 90% of Norwegian landings and an even larger share of what is processed.[12] Data on allocation of raw fish in Iceland was obtained from the trade journal *Útvegur*. However, first-hand values or prices are not available. We, therefore, use market prices for finished products to represent prices.[13] To make the data series comparable, all values were converted to US dollars where necessary. Data on exchange rates were obtained from International Financial Statistics.

The Choice of Product Form

In this section, we look at the allocation of cod landings to the production of different product forms. We first look at this process for cod in Norway, and a similar investigation will be undertaken for Iceland. As noted above, we do not have the necessary data to undertake a similar analysis for Canada.[14] From the empirical analyses, we report only descriptive statistics and elasticities, as these contain all the relevant economic information. However, the parameters are available upon request from the authors. Together with the elasticities, R^2, a Durbin-Watson test against autocorrelation and a Wald test for the null hypothesis that the explanatory variables jointly are not significantly different from zero are reported. Since autocorrelation does not seem to be a problem, as all test statistics either cannot provide evidence against the null hypothesis of no autocorrelation or are in the inconclusive interval, and since the explanatory variables jointly are statistically significant in all equations, we do not comment any further upon these tests.

The Links Between Different Product Forms in Norway

As shown in table 1, frozen products is the main product category, with a share of 50.6%. Although some of this is whole fish, it is basically frozen fillets. Salted cod is the other main product, with a share of 32%. Dried cod, while historically important, has declined in importance for a long time and is now down to a share of 8.9%. Fresh cod is rather unimportant, with a share of 8.4%.

The elasticities are reported in table 2. With the exception of frozen cod, the supply of all product forms is elastic. The elasticity for frozen cod is fairly close to one, 0.94, and is not significantly different from one. As expected, all product forms are substitutes, so that changes in relative prices will influence the production pattern. These relationships seem to be strong between all product forms, except for fresh cod, which seems to have a much weaker relationship to the other product forms. This may be explained by the fact that the quality of fresh fish is often higher, especially with respect to freshness than for input to other kinds of products.

---

[12] Landings south of the area covered by Norges Råfisklag mainly supply the domestic market for fresh cod.
[13] Since the Law of One Price holds for the prices of finished product, this should not make much of a difference.
[14] A similar analysis is undertaken by Gordon, Hannesson, and Bibb (1993) for the three product forms (frozen, salted, and dried) in Norway. However, they do not report own-price elasticities.

The result that frozen cod shows a smaller supply elasticity is consistent with the hypothesis that this type of processing operates under a tighter capacity constraint than the other product forms.

The Links Between Different Product Forms in Iceland

In table 1, the relative shares are shown for the different product forms in Iceland. Freezing is the most important form of processing and takes, on average, 50% of the landings. As for Norway, salting is the other main product form, taking 39% of the landings. The fresh segment is slightly more important in Iceland, accounting for 10.6% of the landings, but dried cod has disappeared as a product form over the period (in the first half of the 1980s, a small part of the landings was used for production of dried cod).

The elasticities are reported in table 3. The supply of all product forms is elastic, although barely so for salted cod, and very much so for fresh cod with an elasticity of 2.4. This is contrary to the results for Norway and contrary to what one would expect. A possible explanation may be the different industry structure, as

Table 1
Descriptive Statistics and Production Shares for Cod

Norway	Fresh	Salted	Frozen	Dried
Mean	0.084	0.320	0.506	0.089
St. dev.	0.030	0.153	0.147	0.096
Iceland	**Frozen**	**Salted**	**Fresh**	
Mean	0.503	0.390	0.106	
St. dev.	0.132	0.153	0.069	

Table 2
Price Elasticities Between Different Product Forms, Norway

	i = Fresh	i = Salted	i = Frozen	i = Dried
$e_{i,Fresh}$	1.007*	–0.162*	–0.036	–0.161
	(0.239)	(0.076)	(0.038)	(0.117)
$e_{i,Salted}$	–0.616*	1.602*	–0.715*	–1.104*
	(0.292)	(0.220)	(0.117)	(0.335)
$e_{i,Frozen}$	–0.220	–1.132*	0.940*	–1.064*
	(0.232)	(0.186)	(0.131)	(0.364)
$e_{i,Dried}$	–0.171	–0.307*	–0.187*	2.330*
	(0.123)	(0.093)	(0.064)	(0.330)
R^2	0.258	0.693	0.542	
DW[a]	1.943	2.101	2.292	
Wald(4)[b]	12.227*	44.439*	146.899*	

Notes: Standard errors in parentheses. * Indicates significant at a 5% level.
[a] Critical value at a 5% level for the upper bound of the DW test is 1.943 and the lower bound 1.599.
[b] This is a Wald test for the hypothesis that all parameters, except the constant term, equal zero with degrees of freedom in parentheses. The critical value at a 5% significance level is 9.49.

Table 3
Price Elastisities For Different Product Forms, Iceland

	i = Fresh	i = Salted	i = Frozen
$e_{i,Fresh}$	2.461*	0.080	–0.582*
	(0.248)	(0.116)	(0.068)
$e_{i,Salted}$	0.293	1.057*	–0.881*
	(0.426)	(0.231)	(0.141)
$e_{i,Frozen}$	–2.754*	–1.137*	1.463*
	(0.323)	(0.181)	(0.137)
R^2	0.432	0.591	
DW[a]	2.184	1.963	
Wald(3)[b]	66.424*	20.301*	

Notes: Standard errors in parentheses. * Indicates significant at a 5% level.
[a] Critical value at a 5% level for the upper bound of the DW test is 1.931 and the lower bound 1.610.
[b] This is a Wald test for the hypothesis that all parameters, except the constant term, equal zero with degrees of freedom in parentheses. The critical value at a 5% significance level is 7.82.

more Icelandic firms produce both product forms, while Norwegian processors tend to specialize. Frozen cod is clearly a substitute for the other product forms, and all cross-price elasticities related to frozen cod are highly significant. The relationship between fresh and salted cod is weak, with positive cross-price elasticities (indicating complementarity), but very close to and not significantly different from zero. The significant supply elasticities imply that changes in relative prices will, to a large extent, determine the production pattern. The fit of the equations is satisfactory, although not very high.

Allocation Between Markets

In this section, we will use the supply equations derived from a translog revenue function to investigate the allocation of frozen cod fillets between markets. This decision is conditioned on the allocation of a share of the landings to be used as input in this processing process. We first look at Norway, then Iceland, and finally Canada. Again, we report only descriptive statistics and elasticities, as these contain all the relevant economic information. Together with the elasticities, R^2, a Durbin-Watson test against autocorrelation and a Wald test for the null hypothesis that the explanatory variables jointly are not significantly different from zero are reported. Again, since autocorrelation does not seem to be a problem, as all test statistics either cannot provide evidence against the null hypothesis of no autocorrelation or are in the inconclusive interval, and since the explanatory variables jointly are statistically significant in all equations, we do not comment any further upon these tests.

Supply Relationships — Norway

We start by modeling the allocation of frozen cod fillets from Norway to the markets in France, Germany, the UK, and the US. Exports to the US are disaggregated into frozen block and frozen fillets. Descriptive statistics for the export shares are shown in table 4, and the elasticities are shown in table 5.

For Norway, the UK is the most important market, with an export share of

57.6%, followed by the two US segments, while the export shares to France and Germany are both just below 10%. With the exception of the UK, all supply elasticities are above one (elastic), while for the UK the elasticity is 0.7. All the supply elasticities are significantly different from zero. It is noteworthy that the supply elasticity is highest for the smaller markets, which indicates that these are fringe markets.

The cross-price elasticities indicate that all markets are substitutes, implying that supply responds to relative prices. However, judging by the cases where the cross-price elasticities are significantly different from zero, the internal links between the European markets and the two US product forms seem to be stronger than the links between Europe and North America. A problem with the model is that the fit of the equations is relatively poor and much more so than the equations, above, for the product forms.

Table 4
Descriptive Statistics and Export Shares

Norway	UK	France	US Block	US Fillets	Germany
Mean	0.576	0.077	0.123	0.130	0.092
St. dev.	0.139	0.051	0.122	0.085	0.084
Iceland	**US Block**	**US Fillets**	**UK**		
Mean	0.150	0.457	0.392		
St. dev.	0.102	0.158	0.187		
Canada	**US Block**	**US Fillets**	**UK**		
Mean	0.417	0.528	0.054		
St. dev.	0.102	0.116	0.051		

Table 5
Price Elasticities For Different Markets, Norway

	i = UK	*i* = France	*i* = US Block	*i* = US Fillets	*i* = Germany
$e_{i,UK}$	0.701*	–3.797*	–0.577	–0.082	–1.987*
	(0.097)	(0.716)	(0.633)	(0.446)	(0.816)
$e_{i,France}$	–0.238*	2.999*	–0.095	0.357	0.291
	(0.154)	(0.724)	(0.356)	(0.273)	(0.514)
$e_{i,USblock}$	–0.128	–0.152	3.695*	–1.807*	–1.468*
	(0.135)	(0.168)	(0.785)	(0.482)	(0.589)
$e_{i,USfill}$	–0.018	0.602*	–1.908*	1.392*	0.197
	(0.100)	(0.461)	(0.509)	(0.504)	(0.462)
$e_{i,Germany}$	–0.317*	0.346	–1.094*	0.139	2.968*
	(0.130)	(0.612)	(0.439)	(0.326)	(0.708)
R^2	0.191	0.348	0.246	0.020	
DW[a]	1.938	2.238	2.289	1.887	
Wald(5)[b]	22.637*	16.239*	22.712*	33.645*	

Notes: Standard errors in parentheses. * Indicates significant at a 5% level.
[a] Critical value at a 5% level for the upper bound of the DW test is 1.841 and the lower bound 1.707.
[b] This is a Wald test for the hypothesis that all parameters, except the constant term, equal zero with degrees of freedom in parentheses. The critical value at a 5% significance level is 11.07.

Supply Relationships — Iceland

For Iceland, only the markets in the UK and the US are considered, as the quantities exported to France and Germany are very limited. Descriptive statistics for the export shares are shown in table 4, and the elasticities are shown in table 6.

For Iceland, the US market for fillets is the most important one, with an export share of 45.7%. The UK market is also important with exports totaling 39.2%, while the remaining 15% go to the US block market. The supply to the US block market is inelastic, while it is elastic to the other two segments. All the supply elasticities are significantly different from zero. In contrast to the results for Norway, it is the smallest market that has the lowest supply elasticity. However, one should also note that although block fillets are the smallest product form for Iceland, its market share is substantially higher than that of the smallest markets of Norway and Canada. Furthermore, frozen block is often regarded as the lowest quality product among the frozen cod products.

The cross-price elasticities indicate that all markets are substitutes, implying that supply does respond to relative prices. However, only between US fillets and the UK are the cross-price elasticities significantly different from zero. However, the fit of the model's equations is relatively poor.

Supply Relationships — Canada

For Canada, as for Iceland, only the markets in the UK and the US are considered, as the quantities exported to France and Germany are very small. Descriptive statistics for the export shares are shown in table 4, and the elasticities are shown in table 7.

For Canada, the US is the most important market, with an export share of 52.8% for fillets and 41.7% for block fillets. The remaining 5.4% goes to the UK market, and hence, Canada is only a limited source of supply to this market. All supply elasticities are greater than one (elastic), with the UK as the most elastic, and all the supply elasticities are significantly different from zero. This is similar to the results for Norway, again indicating that the smallest market (the UK) is a fringe market.

Table 6
Price Elastisities For Different Markets, Iceland

	i = US Block	i = US Fillets	i = UK
$E_{i,USBlock}$	0.666	–0.010	–0.244
	(0.483)	(0.138)	(0.155)
$e_{i,USFill}$	–0.029	1.257*	–1.452*
	(0.419)	(0.223)	(0.229)
$e_{i,UK}$	–0.636	–1.247*	1.697*
	(0.405)	(0.197)	(0.265)
R^2	0.316	0.173	
DW[a]	2.271	1.719	
Wald(3)[b]	38.095*	28.150*	

Notes: Standard errors in parentheses. * Indicates significant at a 5% level.
[a] Critical value at a 5% level for the upper bound of the DW test is 1.802 and the lower bound 1.665.
[b] This is a Wald test for the hypothesis that all parameters, except the constant term, equal zero with degrees of freedom in parentheses. The critical value at a 5% significance level is 7.82.

Table 7
Price Elasticities For Different Markets, Canada

	i = US Block	*i* = US Fillets	*i* = UK
$e_{i,USBlock}$	1.385*	–1.039*	–0.513
	(0.214)	(0.146)	(0.830)
$e_{i,USFill}$	–1.369*	1.241*	–1.974*
	(0.213)	(0.165)	(0.765)
$e_{i,UK}$	–0.066	–0.201*	2.487*
	(0.107)	(0.078)	(0.713)
R^2	0.438	0.439	
DW[a]	2.027	2.062	
Wald(4)[b]	20.080*	24.916*	

Notes: Standard errors in parentheses. * Indicates significant at a 5% level.
[a] Critical value at a 5% level for the upper bound of the DW test is 1.841 and the lower bound 1.707.
[b] This is a Wald test for the hypothesis that all parameters, except the constant term, equal zero with degrees of freedom in parentheses. The critical value at a 5% significance level is 7.82.

The cross-price elasticities indicate that all markets are substitutes, implying that supply responds to relative prices. However, the relationships are much stronger between the two product forms going to the US than between these product forms and the exports to the UK. Although the fit of the equations is better here than in the preceding cases, it is still relatively poor.

Concluding Remarks

The results presented herein clearly indicate responsiveness to changes in relative product prices among suppliers, supporting what one would otherwise suspect must be behind the statistical relationships between product prices in different, geographically separated markets. However, the results for the countries and products investigated differ in important ways. One would expect less elastic supply for a relatively capital-intensive industry, like freezing, than for more flexible industries, like salting or fresh fish, which hardly require any processing at all. This is supported by the results for Norway, but not those for Iceland. One would also expect a higher supply elasticity for small markets, as these would likely be fringe markets into which one would venture occasionally. This is supported by the results for Norway and Canada, but not those for Iceland. One can only speculate why the structure of Iceland differs from Canada and Norway. However, there are differences with respect to firm structure in the value chain, fisheries management, and government support (Hannesson 1996).

In the allocation between different product forms, most were found to be substitutes, but fresh and salted cod seem to be independent in Iceland. Hence, in general, relative prices are important because they dictate the product form marketed. However, there does not seem to be a clear pattern with respect to which of the product forms are more elastic than others. In Iceland, salted cod is the least elastic product form, while in Norway it is the most elastic product form together with dried cod, the other traditional product form. Hence, it is not obvious from these results which product forms are most exposed to competition, since the reaction would be different for Icelandic and Norwegian processors. This is also important when considering the impact of new market competitors, like Alaska pollock, in the cod market. As Alaska pollock and other new, competing whitefish species are mostly marketed as frozen fillets, the initial effect will be pressure on fillet prices. However, the high degree of market integration will ensure that this effect will be reflected in the prices for all cod products. Both in Iceland and Norway, the substitution effect with respect to frozen fillets is strongest for salted cod. Hence, a substantial part of the cod that is not used as frozen fillets will show up as salted cod. However, in Iceland the supply of fresh cod will also increase, while in Norway there does not seem to be any effect for fresh cod, but some for dried cod.

For the allocation of frozen cod fillets, the explanatory power of the estimated equations was not very high. Hence, changes in relative prices do not seem to explain the trade pattern too well. There is a tendency for supply elasticities to be inversely related to the share of the product exported to a specific market, so that supply is least elastic for the most important market for each of the suppliers. The cross-price elasticities also indicate that there is a link between European and North American markets. However, as the elasticities seem to have higher magnitudes within Europe and North America than between the continents, the links are closer within these areas.

It is also worthwhile to note that most supply elasticities are high and that many of the cross-price elasticities are relatively high. This indicates that the processing industries are highly competitive, and any changes in one segment will have substantial effects in other segments. It is also of interest to note that most supply elasticities reported for fishermen seem to be low, and often very low (Squires, 1987a,b; Kirkley and Strand 1988; Squires and Kirkley 1991; Salvanes and Steen 1994; Salvanes and Squires 1995). Hence, the processing sector and the allocation of fish between product forms seem to be substantially more price responsive than the total supply of cod. This difference is not entirely surprising, given the different structure of the two sectors. Fishermen harvest from a limited resource, and although they are sensitive to market signals, the availability of the resource puts limits on how responsive they can be. Processors, on the other hand, compete for landed fish, and any product form will be produced and any market supplied only if the returns on the fish in these uses are as high as alternative returns. This difference between the harvesting and processing sectors is certainly an important structural feature for the whole industry.

References

Asche, F. 2001. Testing the Effect of an Anti-Dumping Duty: The US Salmon Market. *Empirical Economics* 26:343–55.

Asche, F., H. Bremnes, and C.R. Wessells. 1999. Product Aggregation, Market Integration and Relationships Between Prices: An Application to World Salmon Markets. *American Journal of Agricultural Economics* 81:568–81.

Asche, F., O. Flaaten, J.R. Isaksen, and T. Vassdal. 2002. A Note on Derived Demand and Relationships Between Prices at Different Levels in the Value Chain. *Journal of Agricultural Economics* 53:101–07.

Asche, F., D.V. Gordon, and R. Hannesson. 2002. Searching for Price Parity in the European Whitefish Market. *Applied Economics* 34:1017–24.

Asche, F., and R. Hannesson. 1997. On the Global Integration of the Markets for Whitefish. Foundation for Research in Economics and Business Administration, SNF Report 98/97.

Bockstael, N. 1977. A Market Model for New England Groundfish Industry. Agricultural Experiment Station Bulletin No. 422. Department of Resource Economics, University of Rhode Island, Kingston, RI.

Bose, S., and A. McIlgrom. 1996. Substitutability Among Species in the Japanese Tuna Market: A Cointegration Analysis. *Marine Resource Economics* 11(3):143–56.

Chambers, R.G. 1988. *Applied Production Analysis: A Dual Approach.* Cambridge: Cambridge University Press.

Christensen, L.R., D.W. Jorgenson, and L.J. Lau. 1973. Trancendental Logarithmic Production Frontiers. *Review of Economics and Statistics* 55:28–45.

FAO. 2000. www.fao.org/fi

Gordon, D.V. 1989. A Revenue Function Approach to the Measurement of Output Substitution Possibilities in Agriculture. *Journal of Economics and Business Statistics* 7:483–87.

Gordon, D.V., and R. Hannesson. 1996. On Prices of Fresh and Frozen Cod. *Marine Resource Economics* 11(4):223–38.

Gordon, D.V., R. Hannesson, and S. Bibb. 1993. Testing for Output Substitution Possibilities in Cod Fish Processing in Norway. *Marine Resource Economics* 8(1):17–30.

Gordon, D.V., K.G. Salvanes, and F. Atkins. 1993. A Fish Is a Fish Is a Fish: Testing for Market Linkage on the Paris Fish Market. *Marine Resource Economics* 8(4):331–43.

Gorman, W.M. 1959. The Demand for Fish, an Application of Factor Analysis. Research Paper No. 6 Series A. University of Birmingham, Birmingham, AL.

Hannesson, R. 1996. *Fisheries Mismanagement: The Case of the North Atlantic Cod*. Oxford: Blackwell.

Hatcher, A., and K. Robinson. 1999. *Overcapacity, Overcapitalisation and Subsidies in European Fisheries*. Portsmouth: University of Portsmouth.

Jaffry, S., S. Pascoe, G. Taylor, and U. Zabala. 2000. Price Interactions between Salmon and Wild-Caught Fish Species in the Spanish Market. *Aquacultural Economics and Management* 4:157–68.

Kirkley, J.E., and I.E. Strand. 1988. The Technology and Management of Multispecies Fisheries. *Applied Economics* 20:1279–92.

Mazany, L., N. Roy, and W.E. Schrank. 1996. Multi-product Allocation under Imperfect Raw Material Supply Conditions: The Case of Fish Products. *Applied Economics* 28:387–96.

McFadden, D. 1978. Cost, Revenue and Profit Functions. *Production Economics: A Dual Approach to Theory and Applications*, M. Fuss and D. McFadden, eds. Amsterdam: North-Holland.

Milazzo, M. 1998. *Subsidies in World Fisheries*. World Bank Technical Paper No. 406. Washington, DC: The World Bank.

Salvanes, K.G., and D. Squires. 1995. Transferable Quotas, Enforcement Costs and Typical Firms: An Empirical Application to the Norwegian Trawler Fleet. *Environmental and Resource Economics* 6:1–21.

Salvanes, K.G., and F. Steen. 1994. Testing for Relative Performance between Seasons in a Fishery. *Land Economics* 70:431–47.

Schrank, W.E., and N. Roy. 1991. *Econometric Modelling of the World Trade in Groundfish.* Dordrecht: Kluwer.

Squires, D. 1987a. Long-Run Profit Functions for Multiproduct Firms. *American Journal of Agricultural Economics* 69:558–69.

___. 1987b. Public Regulation and the Structure of Production in Multiproduct Industries: An Application to the New Engalnd Otter Trawl. *Rand Journal of Economics* 18:232–47.

___. 1987c. Fishing Effort: Its Testing, Specification, and Internal Structure in Fisheries Economics and Management. *Journal of Environmental Economics and Management* 14:268–82.

Squires, D., and J.E. Kirkley. 1991. Production Quota in Multiproduct Pacific Fisheries. *Journal of Environmental Economics and Management* 21:109–26.

Thurman, W.N. 1986. Endogeneity Testing in a Supply and Demand Framework. *Review of Economics and Statistics* 68:638–46.

Toft, A., and T. Bjørndal. 1997. The Structure of Production in the Norwegian Fish-Processing Industry: An Empirical Multi-Output Cost Analysis Using a Hybrid Translog Functional Form. *Journal of Productivity Analysis* 8:247–67.