

Market Integration of Fish in Europe

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Abstract

This paper examines market integration between fish species in Europe, taking international market integration into account. Based on Juselius (2006), market integration is found both on the fresh and frozen markets. The Law of One Price is in force on the fresh market within the segments of flatfish and pelagic fish. Assuming transitivity, a loose form of market integration is identified between 13 fresh and seven frozen fish species, and the relative prices are found fairly stable. The policy implication is that catch limitation measures implemented through the Common Fisheries Policy have limited and conditional effects on prices, because of the large size of the market and varying market integration. Therefore, many fishermen are not ‘compensated’ by price increases as a result of catch limitation measures.

Keywords: *Cointegration; common trends; driving forces; Law of One Price; market integration; price formation; weak exogeneity.*

JEL classifications: *C32, Q22.*

1. Introduction

Several fish stocks in European waters are outside safe biological limits and fishing is unsustainable (International Council for Exploration of the Sea, 2007). As a consequence, many measures have been implemented over the last two to three decades to improve the condition of the stocks. Within the European Union (EU), measures are implemented through the Common Fisheries Policy. ‘Total allowable catches’ is the main element – fixing annual quotas for the most important fish

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species – allocated to each member state through the ‘relative stability’ principle.² For some heavily fished species, recovery plans are also in place. In essence, the purpose behind the measures of the recovery plans is to limit catches and protect stocks in the short run to improve long-run catches. The consequence of using these measures is decreased earnings in the primary fishery in the short run, unless price increases compensate for this.

Are price increases a result of catch limitations? Or, is the price of the species formed in a large integrated market consisting of many species where the effect is dissipated over several species and therefore negligible? This issue is addressed here by examining market integration between fish species in the European raw fish market, including both own supply and imports. The basic assumption is that markets for individual species are integrated between the European countries with a focus on integration between species at the European level. If the prices are integrated between fish species, EU catch limits on specific species will have limited price effects. If the markets for different fish species are separate, the effects on prices might be substantial.

Market integration analysis reveals whether prices of different goods follow each other over time and can thus be considered as being formed within the same market. As the time series of prices appear non-stationary, as indeed is the case for most time series of prices, cointegration analysis must be used. Cointegration analyses can only be undertaken with relatively few variables – because variables are explained by their own lagged variables – and systems; they therefore quickly become too large. In the present analysis, 23 fish species are subject to quotas in the EU, but it is beyond the scope of the cointegration methodology to include 23 possibly separate prices in a single estimation. The 23 species are segmented here according to characteristics such as type of fish, colour of meat, size of fish, price level and fat content.

Our analysis follows the now-established cointegration methodology as documented in Juselius (2006). The methodology uses multivariate tests to identify non-stationary variables and bases the choice of cointegration rank mainly on the trace test.³ Finally, it makes it possible to find common driving trends and thereby identify the degree to which price variables are driven by themselves and other prices.

Knowledge of market integration could be used actively in quota setting in the Common Fisheries Policy. Today, quota setting is mainly based on biological considerations as recommended by the International Council for Exploration of the Sea in their annual advice (International Council for Exploration of the Sea, 2007). The economic consequences of changed quota setting might also be a concern, though the effect on prices is not part of the current policy consideration. An economic optimal fisheries policy would consider these factors. Finally, the issue is important for understanding and quantifying the impact of the external EU trade

²The relative stability principle is the founding element of the Common Fisheries Policy. It states that each member state’s share of the ‘total allowable catch of each fish stock in community waters’ is fixed.

³To qualify the results of the trace test, other rank indicators such as graphs of the co-integrating relations, characteristic roots, number of columns in the α -matrix with significant parameters and economic interpretability are also examined.

policy, e.g. with regard to anti-dumping complaints against Norwegian salmon⁴ or farmed fish supplied by third countries. Globalisation trends will undoubtedly further increase the influence of the market for EU fisheries and fish processing, in particular, the markets for frozen products.

This analysis is made on the European level because earlier studies indicate that markets for individual fish species in different European countries are formed within the same market. Gordon and Hannesson (1996) identified strong integration of markets for frozen cod fillets in the UK, France and Germany. The same authors found integrated markets for frozen haddock (UK and France) and redfish (Germany and France). They also found relatively strong integration of markets for fresh cod in France, the UK and Germany. Nielsen (2005) identified strong integration of European cod markets and partially integrated saithe markets, and Nielsen (2004) found that the Law of One Price (LOP) is in force between the Norwegian and Danish herring markets. The picture is fragmented because evidently only a fraction of the national markets were considered. It is also incomplete because imports into Europe were not included in all cases. On this basis, the present analysis is performed for the whole European market, including imports, thereby implicitly assuming that markets for all the individual species are integrated country-wise.

The first hypothesis is that the European fish markets for categories of similar species are integrated. The reason for this expectation is that earlier country-wise studies indicate integration between species showing more or less the same characteristics. Asche *et al.* (2004) concluded that the whitefish market (cod, haddock and saithe) in France is highly integrated and whitefish can be represented as a single species. Jaffry *et al.* (2000) found an integrated market for tuna, whiting and hake in Spain, but this market is, however, not integrated with salmon. The same authors indicate that the Spanish markets for whitefish (hake, cod and whiting) and pelagic fish (tuna and sardines) are separate.

The second hypothesis is that markets for fresh and frozen fish are not integrated. Fresh and frozen products are not expected to form part of the same markets because of distribution differences, geographical dimension of the markets, the actors involved and consumer preferences.

This paper consists of six sections. In section 2 the methodology is presented, followed by data description in section 3. In section 4 analysed product segments are identified, followed by results in section 5. Finally, in section 6 modelling and policy implications are discussed.

2. Methodology

According to Stigler (1969), a market is defined as 'the area within which the price is determined, allowances being made for quality differences and transport costs'. If prices of different goods are determined within the same market, prices develop equally over time. Based on this definition, the present paper uses econometric tests to identify integration of European firsthand markets for different fish species.

⁴See Kinnucan and Myrland (2002) for more information on the EU anti-dumping complaints against Norwegian salmon and the agreement between the EU and Norway which was in place from 1997–2003.

Whether the prices of different fish species are formed within the same market can be determined by testing the LOP. The LOP is fulfilled when prices of different species move closely together over time. Tests can be undertaken for stationary price series in a multivariate set-up by extending the Stigler (1969) bivariate framework and following the Ravallion (1986) N -market case by estimating equation (1) for, for example, four goods:

$$\ln(p_{1,t}) = A + B\ln(p_{2,t}) + C\ln(p_{3,t}) + D\ln(p_{4,t}) + \varepsilon_t, \quad (1)$$

where $(p_{1,t})$ is the price of Good 1, $(p_{2,t})$ the price of Good 2, $(p_{3,t})$ the price of Good 3, $(p_{4,t})$ the price of Good 4 and where $B + C + D = 1$ implies that the LOP is in force. The regression is valid only for stationary price series. For non-stationary price series, cointegration 'is a natural extension' (Asche *et al.*, 2004). However, regressing price series integrated of different orders may cause spurious correlations.

For price series integrated of the same first order, the Johansen cointegration rank procedure is used and a vector autoregressive (VAR) model in error-correction form is formulated as given in equation (2):

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \dots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-1} + \mu + \Psi D_t + \varepsilon_t, \quad (2)$$

where X_t is a vector of prices and D_t is a vector of other deterministic components, such as seasonal dummies and dummies for outliers. $\Gamma_1, \dots, \Gamma_{k-1}$, Π , μ and Ψ are all parameters. The matrix Π is the long-run solution to the VAR model and contains the possible cointegrating relationship. The number of cointegrating relationships in Π is chosen on the basis of the now-established cointegration methodology, as documented in Juselius (2006).

The rank of Π determines the number of stationary linear combinations of the variables in X_t . If the rank is exactly the number of variables minus one, two in the case of three variables, a single integrating factor common to all the price series exists (Asche *et al.*, 1999; Gonzales-Rivera and Helfand, 2001), indicating market integration. If so, Π can be decomposed into $\alpha\beta'$ where α contains the adjustment coefficients and β the cointegrating vectors. The LOP is tested by imposing restrictions on the β matrix following Juselius (2006).

Cointegration tests and tests of the LOP are undertaken for non-stationary price series in order to determine market sizes. When the cointegration test identifies a single integrating factor that is common to all the price series, and the test of the LOP shows that the LOP is in force, the analysed goods are homogeneous, relative prices are constant and markets are closely integrated. If a single common integrating factor is identified and the LOP is rejected, markets are partially integrated and the goods are imperfect substitutes. Where cointegration tests cannot identify one common integrating factor, market integration between goods cannot be identified.

In the present paper, market integration is tested within small segments consisting of several goods. Market integration is found between goods A and B and B and C, but a reliable model with goods A and C could not be found in all cases. In that situation, a loose form of market integration is introduced where the results of the market integration tests are combined with a transitivity assumption. This implies that the markets for goods A and C are loosely integrated. Thereby, three degrees of market integration are identified: close, partial and loose.

Following the tests identifying market sizes and boundaries, tests of weak exogeneity of price series are undertaken to identify causal relationships in integrated

markets, thus allowing the identification of market leaders. Weak exogeneity is tested by imposing restrictions on α , following Juselius (2006).

Finally, common driving trends are found, thereby identifying driving forces in the systems. Where the tests of weak exogeneity identify the direction of shocks, common driving trends identify whether and to what degree a price series is driven by itself and by other price series in the system. Drivers are identified on the basis of a moving-average representation, as opposed to market leaders which appear from a VAR model.

3. Data

The domestic supply of fish for human consumption in Europe was 12.4 million tonnes in 2005, of which 10.3 million tonnes⁵ originated from capture fisheries and 2.1 million tonnes from aquaculture (Eurostat, 2007). The main supplier countries include Spain, Norway, Italy and Iceland. The EU-15 catches for human consumption totalled 4.0 million tonnes and aquaculture production 1.2 million tonnes (2005). Imports from outside the EU-15 amounted to 4.3 million tonnes traded weight and exports 1.7 million tonnes, revealing that the EU-15 is a large net importer of fish. Thus, total supply for domestic consumption is 7.8 million tonnes, roughly corresponding to an EU-15 per capita consumption of fish of 22.4 kg live weight.⁶ The main European consumer countries are located within the EU-15 and include France, Spain and Germany. Consumption consists of several species of whitefish, flatfish, pelagic fish and crustaceans. Cod, salmon, shrimps and tuna are the most important species in consumption terms. Consumption differs considerably between countries. There is a substantial trade between countries, with 1.0 million tonnes imported to the EU-15 from Norway, Iceland and the Faroe Islands, with an additional 4.06 million tonnes traded internally between the EU-15 countries, as a consequence of different endowment of fish in the European countries.

Data on the European supply of fish were obtained from the New Cronos Database (Eurostat, 2007). Supply includes landings in the EU-15 countries, landings in Norway, Iceland and in the Faroe Islands, and import of raw fish to the EU-15.⁷ Landings of all fish species subject to total allowable catches in the EU were included in the analysis.⁸ Data were collected monthly, covering the period January 1995 to December 2005 (132 observations) and are available in volume, value and unit price for 23 fish species. Because of data gaps, it was necessary to combine this source with the national sources for France, Ireland and the Faroe Islands. Data on

⁵ Eurostat (2007) report a total catch of fish of 13.7 million tonnes of which approximately 3.5 million tonnes were used for fishmeal and oil (non-human consumption).

⁶ This number is a low estimate, because foreign trade is measured in traded weight such as gutted and filleted.

⁷ Total import into Norway, Iceland and the Faroe Islands is included in the data to the extent that it is classified as foreign landings. Furthermore, supply includes all products which reach European land at some stage in the product's lifetime, i.e. also if it is exported later on.

⁸ As quotas do not exist in the Mediterranean Sea for any of the species included in the analysis, landings originating there are only included in the analysis if the species are also caught in other fisheries subject to quotas.

aquaculture production were not available on a monthly basis. Therefore, Norwegian and British salmon exports to the EU-15 were used as proxies for salmon production in each of the two countries. The majority of Norwegian and British salmon production is exported to EU-15.

Import of raw material includes the product forms live, fresh, frozen, fresh fillets and frozen fillets, corresponding to the relevant codes under '03 Fish, crustaceans, molluscs and other aquatic invertebrates' in the harmonised system except '0305 Fish, dried, salted and smoked'. To avoid double counting, imports from EU countries, Norway, Iceland and the Faroe Islands were excluded.

Data are provided for single species separately in the fresh and frozen form. An aggregate consisting of total supply (landings, aquaculture production and import) of each species is constructed in fresh and frozen form, respectively. Quantities are measured in liveweight equivalents, and prices are for 1 kg live weight. The data are converted into live weight in order to study supplies which consist of both whole and filleted fish. The official conversion factors of the Food and Agricultural Organisation of the United Nations (2000) are used where 33–50% of the whole fish is used for consumption.

Plaice is mostly landed fresh, but is included in the analysis as 'frozen' because this species is mostly sold frozen. Freshwater fish includes mainly tilapia and catfish. 'Hake' is an aggregate of several different hake species which cannot be separated in the landing statistics of the main supplier country, Spain. 'Landings' of shrimp include only cold-water shrimp, whereas 'import' includes all shrimp species. Summary statistics are presented in Table 1 as annual averages.

Total annual supply of fresh and frozen raw fish consisted on average of 3.3 and 2.5 million tonnes, respectively. Thus, the present analysis covers 5% of the global fish supply and 45% of the European fish supply. The corresponding values are €4.8 and €4.5 billion. The supplies of fresh fish originate from mainly domestic sources where frozen fish are generally imported. Possible reasons for this specialisation include the presence of considerable direct transportation costs for fresh fish over long distances, and indirect costs related to value loss with freshness deteriorating when transportation of fresh fish transport lasts for several days. Self-sufficiency is high for most fresh fish where it differs between species on the frozen fish market. Most frozen species follow the pattern of relatively low self-sufficiency, although species like haddock, saithe, plaice, herring and mackerel are particularly self-sufficient.

4. Product Segments

Cointegration analysis can only be undertaken with a limited number of variables. Therefore, the present estimations cannot be made with all 23 species at the same time. Hence, a strategy is chosen where market integration tests are undertaken with up to four species included simultaneously. Market integration is tested and, when identified, up to two additional species are included. Tests are performed separately for the fresh and frozen fish markets. This procedure is chosen to minimise the estimation effort, leading to a detailed insight into the European fish market. This implies that market integration is tested within segments of only five species, or less.

Fish products are segmented according to: (i) type of species (whitefish, flatfish, pelagic fish and crustaceans); (ii) colour of meat (white, non-white); (iii) size of fish

Table 1
Total supply of fish (landings and imports) in 18 selected European countries, annual average of 1995–2006

	Fresh				Frozen			
	Quantity (tonnes)	Value (€ million)	Price (€/kg)	Self-sufficiency (%)	Quantity (tonnes)	Value (€ million)	Price (€/kg)	Self-sufficiency (%)
Cod	632,000	1,011	1.60	84	436,000	620	1.42	52
Haddock	165,000	196	1.19	100	76,000	87	1.15	82
Saithe	225,000	146	0.65	99	99,000	43	0.43	100
Pollack	10,000	21	2.19	100	525,000	338	0.64	0
Hake	125,000	466	3.74	72	434,000	883	2.03	2
Whiting	49,000	51	1.03	100	1,000	1	1.08	100
Blue whiting	5,000	5	1.03	100	7,000	2	0.33	100
Freshwater fish	3,000	10	3.16	0	83,000	115	1.40	0
Megrim	6,000	19	3.02	95	0	0	1.63	0
Monkfish	7,000	31	4.26	81	16,000	56	3.50	0
Sole	37,000	322	8.77	99	6,000	15	2.48	20
Plaice	—	—	—	—	102,000	182	1.78	98
Lemon sole	11,000	36	3.37	100	0	0	2.25	0
Turbot	4,000	34	8.93	100	0	0	19.48	0
Dab	11,000	12	1.12	100	0	0	2.20	0
Rays	9,000	15	1.69	100	1,000	1	1.27	100
Herring	887,000	271	0.31	100	185,000	78	0.42	100
Mackerel	473,000	328	0.69	100	82,000	56	0.68	91
Anchovies	109,000	177	1.62	98	2,000	2	0.78	0
Salmon	395,000	1,243	3.15	100	103,000	203	1.97	50
Swordfish	11,000	75	6.78	87	25,000	90	3.67	49
Norway lobster	43,000	268	6.29	100	1,000	14	11.38	79
Shrimp	109,000	105	0.96	91	317,000	1,738	5.48	3
Total	3,326,000	4,842	1.46	93	2,501,000	4,524	1.81	22

Source: Eurostat New Cronos Database, Ofimer (1999), Statistics Iceland (2006) and Statistics Faroe Islands (2006).

(small, medium, large); (iv) price level; and (v) fat content (lean and fat).⁹ For each criterion, segments are formed for the six most important species in value terms (four plus two additional species). The implication of this selection process is that blue whiting, megrim, dab and ray are not included in the analysis. That leaves 16 fresh and 13 frozen products to be analysed, as shown in Appendix 1. A total of 162 models are estimated and of these 20 well-specified models reveal some market integration.¹⁰

Juselius (2006) introduces two principles for estimation: specific-to-general (with variables included according to economic theory) and general-to-specific (variables selected according to statistical fit). The specific-to-general principle implies that the species are segmented according to similarity in characteristics. The general-to-specific principle is used where all species within each set are statistically tested.

5. Results

Results are reported in three steps. First, well-specified models with market integration are presented. Product segments with market integration between species are identified and background tests conducted to ensure that all variables are $I(1)$ and to avoid any misspecification. Second, tests for the LOP identifying close market integration and tests for market leaders are reported. Finally, common driving trends are identified.

5.1. Identifying market integration

In this section, market integration of non-stationary price series is identified. However, market integration of price series integrated of the first order can only be revealed in well-specified models with a rank of the number of variables minus one. Therefore, absence of misspecification, $I(2)$ and stationarity, as well as the presence of a rank of the number of variables minus one must be secured before market integration can be reliably identified.

Tests for misspecification included autocorrelation, normality and autoregressive conditional heteroskedasticity (ARCH), and the conclusions of the presence and absence of misspecification problems were obtained at the 5% significance level.¹¹ The tests used were the multivariate LM test for the first- and second-order autocorrelation in the residuals, a multivariate test of normality of the Shenton–Bowman type (Dennis *et al.*, 2005), and univariate LM tests for autoregressive

⁹ Whitefish include cod and similar species which are round, white and bottom-living. The species are cod, haddock, saithe, pollack, hake, whiting and freshwater fish. The size of the fish is subjectively assessed on average at the time of final sale and may, therefore, not necessarily follow official classifications. The species are chosen in such a way that each species is tested in relation to other species with price levels at $\pm 25\%$ of its price.

¹⁰ The 20 well-specified models reveal market integration. The remaining models only reveal that market integration could not be found in well-specified models in which price variables integrated of order one are included. The common characteristics of these models are that market integration remains unproven.

¹¹ The results of the misspecification tests are not reported because of space limitations, but results are available from the authors on request.

conditional heteroskedasticity with degrees of freedom equal to the number of lags. The presence of $I(2)$ was rejected at the 5% level in all the reported results.

For well-specified models, models with a common integrating factor were sought. Models are sought with one to four lags, with a constant restricted to the cointegration space,¹² with and without 11 centred seasonal dummies, and with and without outlier dummies. Dummies for outliers were potentially introduced when the standardised residuals of an observation of a variable were larger than 3.2, following the Bonferoni criterion (Juselius, 2006; Babula *et al.*, 2006). The dummies are transitory and include a value of 1.0 for the outlier observation followed by a value of -1.0 in the following observations. All other values are zero.

In the 20 well-specified models, the rank is determined using the trace test, the characteristic roots, the significance of the α parameters in each cointegration vector and the graphs of the cointegrating relations, following Juselius (2006). However, because of space limitations only results of the trace tests are reported. The results are presented in Table 2.

Models 1 to 12 reveal partial market integration in the fresh market, models 13 to 19 in the frozen market, and model 20 between the fresh and frozen markets. The first line represents model characteristics and rank determination indicators for model 1 of fresh cod and hake prices. The model is identified with two lags, without seasonal correction and with a transitory dummy for the price of fresh cod for outliers in May 1995 and January 2000.

In the bivariate models, the trace test of the null hypothesis of the rank being two or less is rejected, but the null of the rank being one or less is accepted.¹³ In the multivariate models (3, 4 and 6) with three species, the trace tests point towards a rank of two. The consequence is that evidence of cointegration, and thereby of market integration, is stronger in the bivariate models than in the multivariate, although evidence exists in all the models.

Given the determined rank, the presence of unit roots was tested to ensure that all price series were of the same first order. The multivariate test for stationarity was performed with a restricted constant used according to Dennis *et al.* (2005). The null hypothesis is the presence of stationarity of the single variables, tested using chi-squared tests by imposing unit rows in β . The test results are reported in Table 3.

Stationarity is absent at the 5% level in all models because models were selected to fulfil that claim. As all data series are non-stationary and $I(2)$ trends are absent, all data series are integrated of the first order, confirming partial market integration between the species included in each test.

The results reveal integration between fresh and frozen fish markets for salmon (test 20). Integration of fresh and frozen fish markets for capture fish could not be identified. Twelve models identified integration in fresh markets between 13 species,

¹² A restricted constant model is used as opposed to a restricted trend model, as only a form of market integration where relative prices are constant is sought in the present paper.

¹³ These results were obtained using a 5% significance level in all models except in 14 and 15 of frozen cod and hake and plaice respectively. These models were only accepted at the 10% level. A rank of one in models 14 and 15 are further accepted, because the significance of the α parameters in each cointegrating vector and the graphs of the cointegrating relations point towards a rank of one.

Table 2
Model and rank determination

Species	Model*	Johansen tests						Comp. matrix
		Eigenvalues			Trace test†			
		1	2	3	1	2	3	
<i>Fresh</i>								
1. Cod–hake	2ND ₁	0.14	0.02	–	21.96	2.59	–	0.69
2. Cod–whiting	1SD ₁	0.20	0.02	–	32.29	2.44	–	0.59
3. Hake–sole–mackerel	2N	0.34	0.13	0.05	79.80	25.26	7.40	0.66
4. Hake–sole–N. lobster	1N	0.19	0.15	0.05	54.93	27.92	6.46	0.67
5. Hake–lemon sole	1SD ₃ D ₆	0.14	0.05	–	25.60	6.19	–	0.73
6. Monkfish–lemon sole–turbot	1SD ₄ D ₆	0.17	0.13	0.04	46.70	22.47	4.85	0.77
7. Monkfish–lemon sole	1SD ₆	0.13	0.03	–	22.24	4.57	–	0.77
8. Sole–lemon sole	2 ND ₆	0.16	0.05	–	28.89	6.36	–	0.60
9. Herring–mackerel	3S	0.15	0.03	–	25.28	4.30	–	0.63
10. Herring–anchovies	2S	0.14	0.06	–	26.77	7.77	–	0.72
11. Herring–swordfish	1SD ₇ D ₁₀	0.12	0.04	–	22.16	5.23	–	0.74
12. Anchovies–salmon	3SD ₉	0.11	0.05	–	21.58	6.36	–	0.74
<i>Frozen</i>								
13. Cod–haddock‡	3N	0.18	0.03	–	21.48	2.71	–	0.52
14. Cod–hake‡	2N	0.14	0.04	–	18.08	4.16	–	0.72
15. Cod–plaice	2SD ₁₁ D ₁₃	0.11	0.04	–	19.31	4.76	–	0.77
16. Pollack–plaice	4ND ₁₂	0.15	0.04	–	26.35	5.13	–	0.52
17. Hake–plaice	2N	0.22	0.03	–	35.81	3.75	–	0.39
18. Monkfish–plaice‡	2N	0.33	0.03	–	40.27	3.01	–	0.46
19. Plaice–herring	4ND ₁₄	0.14	0.05	–	26.20	6.57	–	0.64
<i>Fresh and frozen</i>								
20. Salmon	3ND ₉ D ₁₅	0.15	0.05	–	27.27	6.31	–	0.69

Notes: *The number indicates the number of lags at which the estimations are undertaken, S = seasonal corrected by introducing 11 centred seasonal dummies, N = not seasonal corrected and D = dummy introduced to correct for outlier observations. D₁ is for fresh cod (1995.05; 2000.01), D₂ is for fresh cod (1995.05), D₃ is for fresh hake (2004.12 and 2005.01), D₄ is for fresh monkfish (1999.12 and 2000.01), D₅ is for fresh sole (1998.06), D₆ is for fresh lemon sole (2004.11), D₇ is for fresh herring (2005.03), D₈ is for fresh mackerel (1998.01), D₉ is for fresh salmon (1999.10 and 1999.11), D₁₀ is for fresh swordfish (1999.08 and 2002.01), D₁₁ is for frozen cod (2000.01), D₁₂ is for frozen plaice (2000.01), D₁₃ is for frozen plaice (2001.05), D₁₄ is for frozen herring (1999.04) and D₁₅ is for frozen salmon (2001.09).

†Bold values are significant at the 5% level, according to critical values known from Johansen (1996).

‡Estimates are for the period 1998.01 to 2005.12.

whereas seven models identified integration in frozen markets between seven species. In the fresh market, haddock, saithe and shrimp formed separate markets, as no relationships between these and other prices was found. On the frozen market, shrimp, freshwater fish, saithe, mackerel, salmon and swordfish formed separate markets, because relationships between these and other prices were not found. Hence, evidence is found of the fresh fish market being more integrated than the

Table 3
Multivariate test for stationarity of price series, given rank $n - 1$

	Species*		
	First	Second	Third
<i>Fresh</i>			
1. Cod-hake	16.68 (<0.01)	9.51 (<0.01)	–
2. Cod-whiting	27.41 (<0.01)	19.69 (<0.01)	–
3. Hake-sole-mackerel	7.91 (<0.01)	7.97 (<0.01)	10.38 (<0.01)
4. Hake-sole-N. lobster	8.39 (<0.01)	12.69 (<0.01)	10.72 (<0.01)
5. Hake-lemon sole	6.30 (0.01)	12.14 (<0.01)	–
6. Monkfish-lemon sole-turbot	12.43 (<0.01)	10.48 (<0.01)	4.47 (0.04)
7. Monkfish-lemon sole	12.84 (0.01)	10.47 (<0.01)	–
8. Sole-lemon sole	13.06 (<0.01)	8.96 (<0.01)	–
9. Herring-mackerel	14.16 (<0.01)	13.73 (<0.01)	–
10. Herring-anchovies	9.13 (<0.01)	4.20 (0.04)	–
11. Herring-swordfish	7.53 (<0.01)	9.45 (<0.01)	–
12. Anchovies-salmon	7.84 (<0.01)	5.17 (0.02)	–
<i>Frozen</i>			
13. Cod-haddock	11.56 (<0.01)	16.06 (<0.01)	–
14. Cod-hake	5.12 (0.02)	8.16 (<0.01)	–
15. Cod-plaice	9.66 (<0.01)	3.73 (0.05)	–
16. Pollack-plaice	16.04 (<0.01)	4.54 (0.03)	–
17. Hake-plaice	28.00 (<0.01)	4.56 (0.03)	–
18. Monkfish-plaice	33.21 (<0.01)	4.40 (0.04)	–
19. Plaice-herring	3.71 (0.05)	13.06 (<0.01)	–
<i>Fresh and frozen</i>			
20. Salmon	10.74 (<0.01)	13.80 (<0.01)	–

Notes: *Stationarity is tested by imposing zero column restrictions on β' for other variables than the one tested for stationarity. For a model with three price series and a rank of two, like model 3, stationarity of the first of three variables is a test of

$$\beta' = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}.$$

frozen fish market. One explanation might relate to consumers access to fish through perishability of fresh fish and storability of frozen fish.

In the fresh market, hake is integrated with most other species (six), followed by sole with four, herring, mackerel and monkfish with three, and cod and lemon sole with two. Most of the tests identify market integration within the type of species (pelagic fish, flatfish and whitefish), but product segments formed on the basis of all characteristics reveal market integration. Hence, the fresh fish market is, in most cases, characterised by integration between similar types of fish, but integration exists between all parts of the market. Assuming transitivity, evidence of all 13 species forming part of the same integrated market exists.

In the frozen fish market, integration is present between cod and hake, and haddock and plaice. Plaice is further integrated with four other species. Hence, cod and, in particular, plaice prices are formed in the same market as several other species, where prices of all other species are only integrated with cod and

plaice. Market integration in the frozen market is determined in product segments based on all the different characteristics: type, colour, size, price and fat content. The five characteristics are of equal importance, as opposed to fresh fish where type dominates. Assuming transitivity, the seven frozen species form part of the same market, as the prices of cod and plaice are formed within the same market and as either the price of cod or plaice is also formed within the same market as the five other species.

The results are in accordance with *a priori* expectations in the sense that all product segments are formed on the basis of similar characteristics. However, some results seem surprising. The markets for fresh salmon and anchovies, those for fresh herring and swordfish, and those for frozen plaice and herring are integrated. These results can be explained by the presence of one or more similar characteristics. Additional explanations remain a matter of speculation.

5.2. Testing for the Law of One Price and market leaders

To identify whether prices are formed within the same closely integrated markets, the LOP is tested. In a closely integrated market, the prices follow each other over time and relative prices are constant. Market leaders are identified by testing weak exogeneity of the single price series. The results of both tests are presented in Table 4.

At the 5% level, the LOP cannot be rejected in seven of the 20 models, and the markets of species included in these models are closely integrated. Markets for fresh and frozen salmon are closely integrated, presumably because the salmon market is overwhelmingly supplied by farmed fish. In the frozen fish market only cod and plaice prices are formed in the same closely integrated market, where close market integration is identified in five cases in the fresh fish market. This underlines the result that the fresh fish market is more integrated than the frozen one. For the fresh fish market, integration appears mainly for flatfish and pelagic fish. Assuming transitivity, the closely integrated flatfish market consists of three species and the pelagic fish market consists of four species.

Table 4 further identifies market leaders by testing weak exogeneity. In the frozen fish market, cod, pollack, hake, monkfish and herring are weakly exogenous to plaice. That is, the price of plaice is formed in a market where other species are market leaders in all the identified models. Furthermore, haddock and hake are market leaders for cod. In the fresh fish market, cod, sole and monkfish are market leaders. Hake prices are formed in markets led by, e.g. cod or sole, whereas herring prices are formed in a market without market leaders.

5.3. Testing for common driving trends

Given the rank of the number of variables minus one, the driving forces behind the single common trend in each of the 20 systems are identified in Table 5. In the present model, with only the price series included, the parameters of the long-run impact matrix C measure the driving forces behind the price series. That is, they identify the extent to which the prices are driven by themselves and by other price series.

The first line shows that the system in model 1 with fresh cod and hake prices is significantly driven only by the cod prices. The high C_{11} value of 0.80 implies

Table 4
 Test for Law of One Price and weak exogeneity given rank $n - 1$ *

	Test LOP†	Weak exogeneity‡		
		First	Second	Third
<i>Fresh</i>				
1. Cod–hake	15.47 (<0.01)	0.01 (0.94)	15.79 (<0.01)	–
2. Cod–whiting	8.87 (<0.01)	0.92 (<0.01)	25.04 (<0.01)	–
3. Hake–sole–mackerel	12.34 (<0.01)	16.83 (<0.01)	1.88 (0.39)	36.43 (<0.01)
4. Hake–sole–N. lobster	9.87 (<0.01)	20.06 (<0.01)	2.55 (0.28)	11.10 (<0.01)
5. Hake–lemon sole	6.45 (0.01)	9.82 (<0.01)	2.24 (0.14)	–
6. Monkfish–lemon sole–turbot	12.81 (<0.01)	0.16 (0.93)	8.33 (0.02)	16.51 (<0.01)
7. Monkfish–lemon sole	1.56 (0.21)	0.01 (0.95)	8.76 (<0.01)	–
8. Sole–lemon sole	0.18 (0.67)	8.78 (<0.01)	5.26 (0.02)	–
9. Herring–mackerel	0.01 (0.91)	6.54 (0.01)	12.08 (<0.01)	–
10. Herring–anchovies	3.75 (0.05)	6.99 (<0.01)	5.23 (0.02)	–
11. Herring–swordfish	1.26 (0.26)	7.91 (<0.01)	4.91 (0.03)	–
12. Anchovies–salmon	8.29 (<0.01)	1.84 (0.18)	8.04 (<0.01)	–
<i>Frozen</i>				
13. Cod–haddock	15.06 (<0.01)	12.42 (0.01)	0.08 (0.77)	–
14. Cod–hake	9.51 (<0.01)	7.54 (<0.01)	3.48 (0.06)	–
15. Cod–plaice	2.30 (0.09)	0.99 (0.32)	8.48 (<0.01)	–
16. Pollack–plaice	12.84 (<0.01)	0.00 (0.98)	15.82 (<0.01)	–
17. Hake–plaice	21.85 (<0.01)	0.52 (0.47)	21.53 (<0.01)	–
18. Monkfish–plaice	33.54 (<0.01)	1.16 (0.28)	34.23 (<0.01)	–
19. Plaice–herring	11.06 (<0.01)	12.84 (<0.01)	0.04 (0.84)	–
<i>Fresh and frozen</i>				
20. Salmon	1.83 (0.18)	7.46 (<0.01)	6.89 (<0.01)	–

Notes: ***Bold** values are significant at the 5% level.

†The LOP is tested by imposing restrictions on the β -matrix where column sums to zero. For a model with three price series and a rank of two, like model 3, the LOP is a test of

$$\beta' = \begin{bmatrix} 1 & -1 & 0 \\ 1 & 0 & -1 \end{bmatrix}.$$

‡Weak exogeneity is tested by imposing zero rows in α . For a model with three price series and a rank of two, like model 3, weak exogeneity of the first price series is a test of

$$\alpha = \begin{bmatrix} 0 & 0 \\ \alpha_{21} & \alpha_{22} \\ \alpha_{31} & \alpha_{32} \end{bmatrix}.$$

that the cod price to a large extent is driven by itself. The price of hake, with the significant C_{21} value of 0.19, is only driven by the price of cod, rather than by itself (C_{22} is insignificant).

In the frozen fish market, plaice price is significantly driven by cod, pollack, hake, monkfish and herring without being significantly driven by itself in any case. The effects of cod, pollack and hake are the greatest. The cod price is significantly and positively driven by haddock (0.20 in model 13) and significantly and negatively by hake. The long-run cod price is also driven by shocks of its own, but the extent remains ambiguous. Model 13 indicates insignificance whereas model 15

Table 5
The long-run impact matrix of the moving-average representation, given rank $n - 1$ *

	C ₁₁	C ₁₂	C ₁₃	C ₂₁	C ₂₂	C ₂₃	C ₃₁	C ₃₂	C ₃₃
<i>Fresh</i>									
1. Cod-hake	0.80	0.01	–	0.19	0.00	–	–	–	–
2. Cod-whiting	1.05	–0.07	–	0.73	–0.05	–	–	–	–
3. Hake-sole-mackerel	0.21	0.34	0.03	0.39	0.63	0.05	0.75	1.23	0.09
4. Hake-sole-N. lobster	–0.02	0.30	0.11	–0.05	0.75	0.28	–0.05	0.72	0.27
5. Hake-lemon sole	0.20	0.28	–	0.56	0.81	–	–	–	–
6. Monkfish-lemon sole-turbot	0.95	0.04	0.07	0.77	0.03	0.06	0.28	0.01	0.02
7. Monkfish-lemon sole	0.98	0.02	–	0.79	0.02	–	–	–	–
8. Sole-lemon sole	0.52	0.44	–	0.60	0.51	–	–	–	–
9. Herring-mackerel	0.44	0.30	–	0.45	0.30	–	–	–	–
10. Herring-anchovies	0.50	0.78	–	0.17	0.27	–	–	–	–
11. Herring-swordfish	0.41	0.93	–	0.26	0.59	–	–	–	–
12. Anchovies-salmon	0.77	–0.14	–	–0.82	0.15	–	–	–	–
<i>Frozen</i>									
13. Cod-haddock	0.02	0.20	–	0.07	0.65	–	–	–	–
14. Cod-hake	0.18	–0.45	–	–0.21	0.54	–	–	–	–
15. Cod-plaice	0.70	0.23	–	0.35	0.11	–	–	–	–
16. Pollack-plaice	1.01	0.00	–	0.27	0.00	–	–	–	–
17. Hake-plaice	0.78	–0.05	–	0.19	–0.01	–	–	–	–
18. Monkfish-plaice	0.78	–0.15	–	–0.10	0.01	–	–	–	–
19. Plaice-herring	–0.02	0.15	–	–0.08	0.70	–	–	–	–
<i>Fresh and frozen</i>									
20. Salmon	0.33	0.35	–	0.45	0.47	–	–	–	–

Notes: *The moving-average representations are identified without restrictions on α and β . Significant coefficients with t -ratios larger than 1.8 are indicated in bold.

shows a significant and high self-driving force (0.70). The prices of the remaining species in the frozen market are highly driven by themselves, with C_{ii} being 0.54 to 1.01.

In the fresh fish market, cod prices are significantly driven only by themselves with high own effects. The price of sole is significantly driven mainly by itself with high own effects, and it is also significantly and positively affected by prices of lemon sole, hake and Norway lobster. Hake prices are significantly driven by themselves with moderate own effect. Hake prices are further significantly and moderately affected by prices of lemon sole, monkfish, cod and mackerel.

According to Table 1, salmon, cod, hake, mackerel and sole possess the largest shares of the fresh fish market. Therefore, the prices of cod and sole drive both themselves and the prices of other species. Hake and mackerel prices, on the other hand, seem to a larger extent driven by other species. The fresh pelagic market is closely integrated with long-run prices of the individual species, driven by themselves only to a low extent, but driven by the prices of several other species. The prices of the single flatfish species are driven by themselves to a large extent with prices of sole and hake as additional drivers. The price of fresh cod drives itself without being affected by those of other species, but with an effect on hake and whiting.

6. Discussion

The results of the present paper reveal that the LOP is in force within the European markets for fresh flatfish, fresh pelagic fish and between frozen cod and plaice. Partial market integration was further identified in 12 fresh and seven frozen fish models. These included all 13 fresh and seven frozen fish species. Market integration between fresh and frozen fish could only be found for salmon.

The results reveal loose market integration at the European level between several species, among which partial and close integration was found in some market segments. Market integration exists mostly at the fresh fish, and also at the frozen fish market. Closely integrated product segments of fresh flatfish and pelagic fish, and a partially integrated market for fresh whitefish were found. For the fresh market, segments with partial and close market integration were mainly identified for similar types of species (flatfish, pelagic fish and whitefish), but other characteristics were also of importance. In the frozen fish market, segments were identified on the basis of all the characteristics.

The first hypothesis (that European fish markets for categories of similar species are integrated) is true for fresh fish, and to some extent also for frozen fish. In the fresh fish market it is surprising that market integration between some of the major Atlantic species, e.g. haddock and saithe with cod and turbot with sole, remains unidentified.

The results further indicate that integration of the frozen fish market is low in terms of the number of species, which may not be surprising given the different characteristics and markets for specific segments of species. Frozen whitefish and shrimps are mainly imported to the EU markets. Frozen pelagic species caught by EU fishermen are mainly exported to Africa, Asia, Eastern Europe and Russia. However, it is surprising that no integration could be identified between the major frozen whitefish species which were expected to develop in an integrated market as indicated by the former country-wise studies of Spain and France (Jaffry *et al.*, 2000; Asche *et al.*, 2004). This might be due to the fact that these studies analyse mainly fresh fish and that fresh fish markets in general are more integrated than frozen fish markets. One reason might also be that frozen fish are always available and therefore do not need substitutes to the same extent as fresh fish.

Finally, the results revealed no indication of integration between the markets for fresh and frozen fish other than salmon. Hence, except for salmon, the second hypothesis (that markets for fresh and frozen fish are not integrated) is true.

The results for market leaders and driving forces are summarised in Figure 1, which shows partial and close market integration between the dominant species. Market leaders based on the tests for weak exogeneity are also provided and the direction of the arrows goes from market leaders to the other species. Species with a large market share are in capital letters. The grey boxes reveal species with large market shares (> 5% of value), which to a large extent are also self-driven (own values in the *C* matrix > 0.5).

Cod and sole seem to act as market leaders of the whole fresh whitefish market which is driven by the prices of other species only to a limited extent. The prices of other whitefish will subsequently follow the trend of the cod prices. The prices of a number of other species tend to change with the price of sole. The diagram suggests two EU consumer markets for fresh whitefish: the north-oriented and cod-driven market for whitefish (cod and whiting) and the southern EU market (hake, sole,

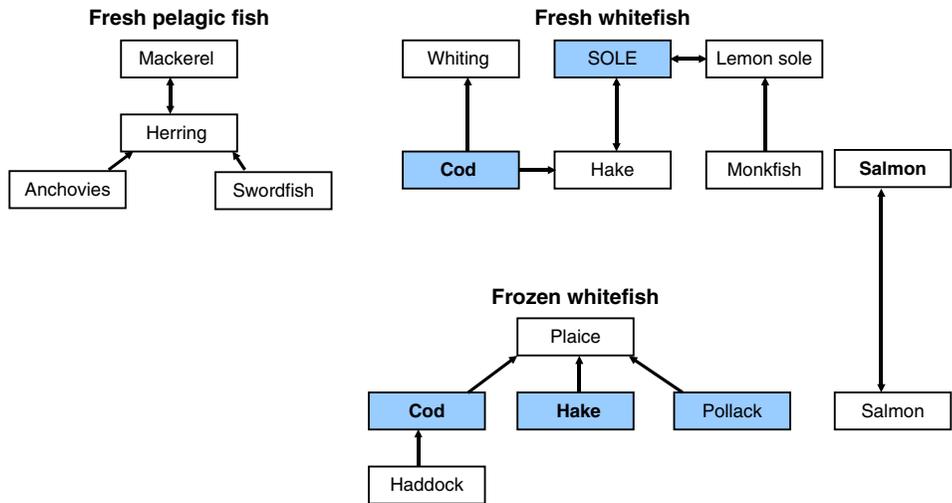


Figure 1. Selected market integration between dominant species

monkfish and lemon sole), with sole as the main driver. Sole and cod obviously make the link between markets for these species in the north and south. The markets for fresh pelagic species were identified as strongly integrated, but without clear drivers. The main drivers for the price formation of the frozen whitefish market seem to originate from three independent sources: cod, hake and pollack (including Alaska pollack). Prices of frozen plaice are mainly driven by these species and are not driven by themselves. The markets for the different frozen pelagic species are, surprisingly, not found to be integrated. The explanation remains a matter of speculation, but storability and, therefore, availability might imply that substitution is not necessary.

The implications of these findings cover methodological and policy issues. On the methodological front, first, the Juselius (2006) cointegration methodology creates new and more reliable knowledge of the markets where price series are integrated of the first order. Second, it creates new structured knowledge on a multi-goods market using product segmentation. Using segments provides for additional and structured information which is otherwise impossible to obtain. Third, the identification of common driving trends reveals information in addition to market leaders, thereby determining whether the prices of the single goods are driven by themselves or other prices. Hence, the methodology reveals more information than earlier studies, and the information is obtained using a more reliable methodology than in earlier studies.

The weakness of the methodology is that cointegration analysis can only be undertaken with a limited number of variables, thereby not obtaining information on the complete system. The results here show market integration in systems with only two and three species, even though systems with up to five species were investigated. Attempts to identify systems with four and five species failed because of misspecification, the presence of stationary and $I(2)$ variables and also on rank grounds.

The reliability of these results might be questioned because the models contain only two and three price variables. Gonzales-Rivera and Helfand (2001) recently

demonstrated that bivariate models are 'inadequate for capturing the spatial dynamics of price adjustments'. Furthermore, the results reveal several examples where market integration is found between species A and B and between B and C, no market integration between A and C and no market integration in a model containing all three species. In reality, variables might be affected by a large number of factors which cannot all be included in cointegration analyses. An ideal study would model all 23 species simultaneously and include all factors that affect these prices, but is probably prevented in practice by data availability. However, combining statistical results on segmented data with a transitivity assumption reveals evidence of loose market integration.

The implications of the results for economic modelling are partly that fish prices must generally be considered segregated in fresh and frozen products, and partly that landings and imports in all the European countries must be analysed. The absence of integration between fresh and frozen fish markets indicates that, when modelling firsthand prices of EU fish landings, it is not necessary to consider imports from outside Europe, though landings in Norway and Iceland should be included. The reason is that 93% of the European supply of fresh fish originates from Europe (Table 1). Price models of fresh pelagic species should include all other major pelagic species, and the prices of the three main frozen whitefish species (cod, pollack and hake) could be modelled in single-species systems. Plaice prices could be modelled in relation to these species and independent of own landings. The prices of frozen pelagic fish could be modelled in single-species systems.

The policy implication of the finding of market integration relates to whether quota reductions implemented through the Common Fisheries Policy are followed by increasing prices, thereby 'compensating' fishermen and making policy reform easier. Given the identified market integration, large price increases are in general not expected as a result of catch limitations. Catch limitation policies will not only have an effect on own prices, but will also increase other prices in the integrated system. As the markets are large, price increases of even large quota reductions of individual stocks will be small. The smaller the price effect, the more markets the species is integrated with, the closer the integration is, and the smaller the share of the European market which it supplies.

Recovery plans are used in the Common Fisheries Policy to improve the condition of the stocks in the long run by limiting short-term catches. The short-term implication is decreasing turnover and earnings of fishermen. Recovery plans are presently in place for North Sea cod, North Sea plaice, sole and northern hake. The short-term catch limitations of these species might cause price increases, given that they possess a significant market share and that each of their markets is unlinked to other fish markets. As the European cod market is mainly supplied by Norway and Iceland, North Sea cod delivers a small share, and a substantial price increase does not appear likely. North Sea plaice supplies a significant share of plaice in Europe, but despite that price increases are unlikely because of the presence of market integration with several other species. North Sea sole supplies the majority of the European fresh sole market, and as sole is a market leader, prices might increase. On the other hand, the possible price increase is limited because sole markets are integrated with those of several other species. Hence, for individual fish species, price increases might follow from catch limitations, but for most species that is not likely.

Fishing quotas within the EU are negotiated once a year in the Council of Ministers. In these negotiations, the 'total allowable catch' for all species in all waters is decided and each member state is allocated a fixed share, following the relative stability principle. The decision is based on advice from the International Council for Exploration of the Sea and the European Commission's Scientific, Technical and Economic Committee for Fisheries. The advice includes biological and, to some extent, economic aspects such as costs and earnings. Improved fisheries management from an economic point of view, however, also requires that price effects are explicitly taken into account. Given integration between species markets, price effects must be treated in a multi-species context, for example by focusing on market leaders such as fresh cod and sole. In fisheries management, price-based fisheries management is the necessary instrument to take prices into account.

The policy implication of the absence of integration between fresh and frozen capture fish species suggests that changes in external tariffs will have only a minor impact on prices obtained by the EU fishermen as they generally land fresh fish. The policy implication of the finding of a close market integration between fresh and frozen salmon is that EU import restrictions on Norwegian salmon only result in frozen salmon being imported from somewhere else.

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Appendix 1. Segments

Criteria	Segment	Fresh	Frozen
1. Species	Whitefish	Cod, haddock, saithe, hake (whiting)	Cod, pollack, hake, freshwater fish (haddock, saithe)
	Flatfish	Monkfish, sole, lemon sole, turbot	Monkfish, plaice
	Pelagic fish	Herring, mackerel, salmon, anchovies (swordfish)	Herring, salmon, swordfish, mackerel
	Crustaceans	Norway lobster, shrimp	–
2. Colour	White	Cod, hake, sole, mackerel (herring)	Cod, pollack, hake, plaice (freshwater fish)
	Non-white	Saithe, Norway lobster, shrimp, salmon	Saithe, shrimp, salmon
3. Size	Small	Sole, herring, mackerel, anchovies	Plaice, herring, mackerel
	Medium	Cod, haddock, saithe hake (whiting)	Cod, pollack, hake, freshwater fish (haddock, saithe)
	Large	Monkfish, salmon, swordfish	Monkfish, salmon, swordfish
4. Price	1 (low)	Saithe, mackerel	Herring, saithe
	2	Shrimp, saithe, haddock	Pollack, mackerel
	3	Cod, anchovies	Haddock, freshwater fish, cod, plaice
	4	Salmon, lemon sole, hake, monkfish	Hake, plaice, salmon
	5	Norway lobster, swordfish	Monkfish, swordfish
	6	Sole, swordfish, turbot	–
5. Fat	Lean (≤ 5 g)	Cod, hake, sole, Norway lobster (haddock, saithe)	Cod, pollack, hake, shrimp (plaice, freshwater fish)
	Fat (> 5 g)	Herring, mackerel, salmon, anchovies	Herring, mackerel, salmon