INTEGRATION AND CAUSALITY IN DEMAND: FARMED TROUT IN GERMANY

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ABSTRACT

In this paper, a new test for causality in demand on markets supplied by both farmed and captured fish is presented. This method is applied on markets for trout and potential substitutes imported to Germany, to identify market delineation and causality in demand. It is found that markets for small portion-sized farmed trout with white meat are relative, but not completely, separate from other fish markets, that markets for these trout are more closely linked to markets for captured fish than to farmed salmon, and that prices on partially integrated markets including trout are weakly exogenous to quantities. The modelling implication is that consistent demand analysis in the present case claims the use of ordinary demand systems. The policy implications are that although the part of the trout business operating with small freshwater ponds remains relatively unaffected by developments on other fish markets, they should pay more careful attention to markets for and management of capture fisheries.

Keywords: Price formation, market integration, causality in demand, trout, captured-farmed fish.

INTRODUCTION

The purpose of this paper is, through a case study of the German market for farmed trout, to contribute to the understanding of price formation in fish markets supplied by both farmed and captured species, and to develop a new approach for the correct specification of demand systems in such markets. Is the market only for trout or does it also consists of other species like salmon and cod? When supply and demand changes and you wish to understand their effect, it is necessary to know whether the market is dedicated to a single species, or is it a larger market consisting of several species. One also needs to know whether prices determine quantities sold or *visa versa*. Market integration analysis is a suitable tool for revealing the adequate delimitation of the markets for farmed and captured fish. Understanding of the role of market integration and substitution in demand allows an assessment of the effects of changing trade policies, of e.g. salmon, and changing fisheries management, of e.g. cod, may have on prices of trout and on the income in the trout business.

Analyses of demand must be based on knowledge of market integration and causality in demand if consistent specifications of demand systems are to be possible. A pre-testing procedure for causality in demand is developed in this paper as part of a suggested extended procedure, in addition to pre-testing for market integration, to be undertaken before estimating demand systems. The subject is analysed within a multivariate co-integration framework by identifying market integration, sizes, and boundaries of markets and causality in demand.

The issue of integration between markets for farmed and capture fish is important, since different developments are taking place in the two areas. Supplies of farmed fish are generally increasing, whereas supplies of captured fish are decreasing or stable. Thus, if for example, trout and salmon markets are linked, the prices of trout would be severely negatively affected by the increasing supply of farmed

Norwegian salmon, but if markets were separate, the prices of trout would remain unaffected. In contrast, if trout markets are linked to cod markets, the prices of trout might have been positively affected by reduced supply of cod from the North Sea, but if these markets are unlinked, cod supply is unimportant. Hence, knowledge of market integration is necessary to assess the potential consequences for the trout business of the introduction of measures such as safeguards and anti-dumping duties on EU imports of Norwegian salmon and of quota restrictions on capture fishing.

The issue is also interesting from a theoretical point of view since the correct specification of demand models requires a good understanding of both the size of relevant markets and of causality. In the Neo-Classical theoretical tradition, price formation has traditionally been studied empirically by estimating demand equations for certain goods, chosen *ad hoc* without pre-tests. The development of new econometric methods, like the analysis of non-stationary time series, co-integration, tests for the Law of One Price (LOP) and tests for market leaders (weak exogeneity tests), over the last decade provides a framework for identifying market integration and structures before specifying demand systems.

Furthermore, in markets for farmed fish, ordinary demand systems with quantities determined by prices are typically chosen in the existing literature. In first-hand markets for capture fish, however, inverse demand systems are preferred, since quantities are presumed exogenously given by the bio-economy, weather, fisheries management etc. On capture fish markets causality goes from quantities to prices, whereas on farmed fish markets the causality is the opposite. In theory, the own-price elasticity in ordinary (price exogenous) and inverse (quantity exogenous) demand systems is equal when inverted. Practical estimations have, however, systematically found that prices are more sensitive to quantities in ordinary demand systems than in inverse demand estimations (Houck 1966, Huang 1994). This leaves the question of whether demand in a market, supplied by both farmed and captured fish, should be modelled in an ordinary or an inverse demand system? Given the presence of perfect market integration between farmed and capture fish markets, the present paper suggests and introduces a test for causality of demand on the aggregate level, as a pre-test for estimating demand systems. The test is performed as a test of weak exogeneity in a co-integrated system, which includes aggregate quantities and prices.

In the economic literature, Guillotreau (2003ab) analyses the structure of European seafood markets after the emergence of farmed salmon. This literature and other articles identify sizes of markets supplied by both farmed and wild caught fish. The main conclusions obtained, include:

- In the UK, the farmed salmon market is not linked to the markets for captured whitefish, such as cod, saithe and haddock (Clay and Fofana 1998).
- In Spain farmed salmon "is at best only a weak substitute for tuna, hake and whiting, but no significant interaction could be found" (Jaffry *et al* 2000).
- In France, ambiguous results on the integration of farmed salmon markets and markets for captured whitefish have been obtained in the literature. Gordon, Salvanes and Atkins (1993) find salmon and whitefish markets separate, whereas Tuncel and Le Grel (1999) find that salmon and whitefish markets are integrated, but cannot find close links between trout and whitefish.
- In Finland, farmed salmon trout, farmed and captured salmon are close substitutes, and the price of imported farmed salmon affects salmon trout prices (Asche *et al.* 2001; Setälä *et al.* 2002; Saarni *et al* 2003). Salmon trout and imported salmon determine the price of wild salmon and sea trout (Setälä *et al.* 2002; Virtanen *et al* 2005).
- In Germany farmed trout does not seem to suffer close competition from other fish species, as it does in other countries (Girac 2002).

It is apparent that results are mixed. Trout is sold in three product forms in Europe; as small portion-sized with white meat, as small portion-sized with red meat and as large salmon trout. In Germany, however, small portion-sized trout with white meat predominates. The consequence is that trout and whitefish might be more closely linked than trout and salmon, owing to the white meat of these species and given that whitefish in Germany are sold in small sizes. This is likely since the stocks of these species in the Northeast Atlantic Ocean supplying Germany are heavily exploited. Thus, the first hypothesis of this paper is that markets for trout and captured whitefish species are integrated in Germany, owing to small fish being sold and to the white meat of these species. Furthermore, since most farmed salmon sold in Germany originates from large-scale farming in Norway whereas most trout originates from small-scale farming, the second hypothesis is that markets for farmed trout and salmon remain unlinked in Germany. Finally, the third hypothesis is that pre-testing identifies causality as being from prices to quantities on trout markets.

METHODOLOGY

A market, according to Stigler (1969), is defined as “the area within which the price is determined, allowances being made for quality differences and transport costs.” Based on this definition, this paper uses econometric tests to determine whether the market trout forms part of a larger market. Co-integration tests and tests of the Law of One Price (LOP) are undertaken in order to determine market sizes and boundaries. When the co-integration test identifies a single integrating factor which is common to all the price series, and the test of the LOP shows that the LOP is in force, the goods analysed are homogeneous, relative prices are constant, and markets are perfectly integrated. If it identifies a single common integrating factor and the LOP is rejected, the markets are partially integrated. Where the co-integration test cannot identify one common integrating factor, the goods might be heterogeneous and their markets independent. Sub-systems for which a single common integrating factor exists are sought by excluding price series one-by-one from the tests until one with a single common integrating factor is identified.

The LOP is tested between prices of trout and potential substitutes. Tests are undertaken in a multivariate co-integration set-up. Extending the Stigler (1969) bivariate framework, the LOP in the multivariate form with three goods included is tested by estimating Equation 1:

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

where ($p_{1,t}$) is the price of Good 1, ($p_{2,t}$) is the price of Good 2 and ($p_{3,t}$) the price of Good 3, and where B+C=1 implies that the LOP is in force. The regression is, however, only valid for stationary data series. For non-stationary data series, co-integration analysis must be used. Therefore, it is necessary to confirm that data series are integrated of the same order (i.e. I(1)).

Based on an I(1) nature of the price series, the Johansen co-integration rank procedure is used and a Vector Autoregressive (VAR) model in Error Correction form is formulated as given in Equation 2:

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

where $\Delta\boldsymbol{X_t}$ is the differenced price series, $\Delta\boldsymbol{X_{t-k}}$ is the price series differenced between the present period and period k, $\boldsymbol{X_{t-1}}$ is a price series in a basic period, and $\boldsymbol{D_t}$ is a vector of other deterministic components, such as seasonal dummies and dummies for outliers. $\Gamma_1 ... \Gamma_{\boldsymbol{k}-1}$, Π, μ and Ψ are all parameters. The matrix Π is the long-run solution to the VAR model and contains the possible co-integrating relationship. The rank of Π determines the number of stationary linear combinations of the variables in $\boldsymbol{X_t}$. If the rank is less than the number of variables minus one but larger than zero, i.e. one in the case of three variables, a common integrating factor does not exist and it is of no relevance to test the LOP. However, if the rank is exactly the number of variables minus one, two in the case of three variables, a single integrating factor which is common to all the price series exists, and Π can be decomposed into $\alpha\beta'$, where α contains the adjustment coefficients and β the co-integrating vectors. In that case, the LOP can be tested.

Based on the chosen rank of the number of variables minus one (two in the case of three variables), the LOP is tested using Likelihood Ratio tests of restrictions imposed on β. In the present multivariate set-up, and assuming that the rank is the number of variables minus one, a test of the LOP is a test of whether the columns in the β matrix sum to zero.

The tests of the LOP are undertaken without any identification problems in all cases, due to the fact that the rank condition of Johansen and Juselius (1994) will always be fulfilled.

The test for causality in demand is developed and performed on the basis of two simple double-logarithmic demand functions with only one good included, respectively in the ordinary and the inverse specification. This is done for aggregates of price and quantity series in the whole integrated market, thus testing causality of the system as a whole. The double logarithmic form follows from a Cobb-Douglas utility function. The models are given in (3):

$$\ln(Q_t) = a_O + b_O * \ln(P_t) \tag{3a}$$
$$\ln(P_t) = a_I + b_I * \ln(Q_t) \tag{3b}$$

where P_t is the average price on the perfectly integrated market, Q_t the total quantity in that market, the *a*'s are constants and the *b*'s the own price elasticities in the ordinary and the inverse demand model, respectively. These regression equations are only valid for stationary data series. For data series integrated of degree one, co-integration analysis must be used. Based on the I(1) nature of the data series, the Johansen co-integration rank procedure is used again. The regression equation remains as in (2), except that $\boldsymbol{X}_t$ now includes the average price and the total aggregated quantity. Given a rank of one, the demand function can be exactly identified, Π decomposed into $\alpha\beta'$, where α contains the adjustment coefficients. Tests of weak exogeneity of the average price and the total quantity now identify causal relationships, thus identifying which data series drive the other without being affected by it. Accepting weak exogeneity identifies the causal relationship.

The test of causality is important in partially integrated markets, not in perfectly integrated markets. The reason is that different goods in perfectly integrated markets can be aggregated to one good in demand analyses, and when demand analyses are performed with only one good, elasticities estimated in ordinary and inverse demand systems are equal when inverted. In such a situation causality does not matter. In partially integrated markets, however, results will differ systematically (Houck 1966; Huang 1994), and it is important to choose the correct specification. The present test is introduced to guide this choice.

DATA

Global supplies of rainbow trout (oncorhynchus mykiss) were 511,000 tonnes in 2002, consisting of 507,000 tonnes from aquaculture and 4,000 tonnes from capture fisheries (FAO 2002ab). Chile (22%), Norway (16%) and France (9%) were the largest aquaculture suppliers. The EU-15 production as a whole amounted to 40%. Global trade in the raw material of trout was 183,000 tonnes live weight in 2002 (FAO 2002b). Japan is the main import market (45%), followed by Germany (8%) and Russia (7%). The EU import market was 21%. Norway (40%) and Chile (20%) are the main suppliers, followed by Denmark (12%). The EU supplied 28%, of which a quarter is headed for non-EU countries (Eurostat 2004).

The EU as a whole is almost self-sufficient. Domestic production consists of three types of product (Eurofish 2004); Red portion-sized trout typically of 600-800 gram mainly produced in France, Italy and Spain (approximately half), white portion-sized trout typically of 200-400 gram mainly from Germany and Denmark (one-third) and red salmon trout larger than 1.5 kg mostly from Finland and France (one-sixth). Larger trout usually originate from sea aquaculture, whereas smaller trout are raised in inland freshwater ponds owned by small-scale firms. Large salmon trout and medium-sized red trout are sold at a global integrated market, where small portion-sized white trout are sold at local markets around Europe.

This paper focuses on the trout market in Germany. In 2002, 24,200 tonnes were raised (Eurostat 2004), of which 85% were small portion-sized trout of 200-400 grams with white meat (Eurofish 2004). 30,200 and 2,600 tonnes, respectively, were imported and exported, making Germany to a substantial net importer of trout. Denmark (52%) and Spain (13%) are the largest suppliers. Data on imports of portion-sized white trout, portion-sized red trout and large salmon trout are not available for 2002, but for 2003 it is known that 80% of German imports of fresh and frozen whole trout consisted of fish smaller than 1 kg, i.e. of portion-sized white and red trout. Thus, German consumption differs from the rest of the EU by being mostly of small portion-sized trout with white meat.

The present analysis uses foreign trade data. Total German imports from all supplier countries are included in the analysis on a monthly basis and cover the period January 1998 to December 2003. With no observations missing the analysis include 72 observations. Owing to data limitations until 2002 it is not possible to study market integration of the three different size classes of trout separately. The implication is that the conclusions only apply to small portion-sized trout with white meat originating from freshwater ponds, since these form the overwhelming majority of trout sale in Germany.

Potential substitutes for trout studied are salmon (*salmo salar*), cod (*gadus morhua*), mackerel (*scomber scumbrus*), halibut (*reinhardtius hippoglossoides*) and redfish (*sebastes species*). The majority of German consumption of all these species is imported. Salmon originates from large-scale sea aquaculture, primarily in Norway, where the other potential substitutes originate from capture fisheries in the North East Atlantic Ocean. Salmon is red and sold mainly large-sized, where the capture species are white and potentially sold in different sizes. In reality, however, most sales of the capture species are in small portions, owing to the fish stocks being heavily exploited.

Data summary statistics are given in Table 1 with prices in nominal terms.

Table 1: Data summary statistics on German import, tonnes and €/kg, annual average 1998-2003

	Quantity	Price		Quantity	Price
Trout:			**Potential substitutes:**		
Fresh	4,529	3.11	Fresh salmon	66,087	3.55
Frozen	6,819	3.14	Fresh cod	3,726	3.07
Fresh fillets	430	5.66	Fresh halibut	547	3.17
Smoked	4,399	7.61	Fresh mackerel	1,557	1.38
Total	16,177	4.41	Fresh redfish	15,245	1.68
			Frozen salmon	1,681	4.37
			Frozen cod	643	3.08
			Frozen halibut	4,941	3.45
			Frozen mackerel	6,747	1.00
			Frozen redfish	2,052	1.84
			Fresh fillets of salmon	6,816	6.07
			Fresh fillets of cod	3,841	5.79
			Fresh fillets of redfish	2,034	5.45
			Smoked salmon	9,310	9.37
			Smoked halibut	299	12.37
			Smoked mackerel	468	2.38

Source: Eurostat Foreign Trade Statistics (Comext).

Total German imports of trout amount to 16,177 tonnes worth €71 million. Measured in quantities frozen trout is the most important item, whereas smoked trout is the most valuable. There are, however, imports of all product forms. Salmon is imported to Germany mainly fresh (whole and as fillets) and smoked, and consumed in these product forms. Fresh whole salmon is, however, also used for smoking in the German industry. Cod is mostly imported and consumed fresh, redfish is also dominated by imports and consumption of fresh fish, mackerel by frozen imports and halibut by frozen whole fish used in the German smokehouses. Hence, unprocessed salmon, halibut and mackerel might be substitutes for trout since they are all raw material for the smoking industry.

RESULTS

The presence of unit roots were tested for, using Augmented Dickey-Fuller tests in order to ensure that all the data series were integrated of the same order. The tests were undertaken with a constant included in the regression. The optimal number of lags in the regressions was chosen according to the Schwarz Information Criteria. Test results are presented in Table 2.

Table 2: Unit Root Tests (Augmented Dickey-Fuller Tests with constant)[1]

	H_0 of non-stationarity:			H_0 of non-stationarity:	
	Level	Difference		Level	Difference
Trout:			**Potential substitutes:**		
Fresh	-1.97 (12)	-1.58 (12)	Frozen salmon	-1.50 (12)	-2.88 (12)***
Frozen	- 0.87 (12)	-4.69 (12)***	Frozen cod	-2.25 (12)	-2.88 (12)***
Fresh fillets	-1.67 (12)	-2.77 (12)**	Frozen halibut	-1.91 (12)	-1.84 (12)
Smoked	-1.38 (12)	-2.94 (12)***	Frozen mackerel	-1.84 (12)	-3.14 (12)***
			Frozen redfish	-1.70 (12)	-2.77 (12)**
			Fresh fillets of salmon	-1.13 (12)	-1.94 (12)
			Fresh fillets of cod	-2.72 (10)**	-4.27 (10)***
			Fresh fillets of redfish	-1.70 (12)	-2.24 (12)
			Smoked salmon	-1.85 (12)	-2.05 (12)
			Smoked halibut	-1.44 (12)	-2.82 (12)**
			Smoked mackerel	-2.58 (12)**	-3.27 (12)***

Notes: 1. The critical values are known from MacKinnon (1991) and are –3.43/-2.86/-2.57, respectively, at 99%, 95%, and 90% levels. ***/** = significance at 1 and 5% levels.

From the left part of Table 2 it appears that the null hypothesis of unit roots in price levels of trout imported to Germany is accepted for all product forms at a 5% level. Moreover, the null hypothesis of unit roots in the differenced price series is rejected for all product forms, except fresh. This implies that evidence of price series of trout being integrated of the same, first, order are only found for frozen trout, fresh fillets of trout and smoked trout.

Given that only prices of frozen, fresh fillets of and smoked trout were found I(1), tests of market integration are performed only between trout and potential substitutes in these product forms. The results of unit root tests for potential substitutes are in the right part of Table 2. It appears that potential substitutes for frozen trout are salmon, cod, mackerel and redfish, with the null hypothesis of non-stationarity in levels and differences all, respectively, accepted and rejected.

Based on the I(1) nature of selected price series, co-integration tests, as well as tests for the LOP and for weak exogeneity, were undertaken between different fish species for each of the product forms. Tests were undertaken starting with all price series until a model without any misspecification problems and with a rank of the number of variables minus one were found. The misspecification tests included autocorrelation, normality, and autoregressive conditional heteroscedasticity (ARCH) tests, and conclusions on the presence and absence of misspecification problems were obtained at the 5% significance level. Results for tests with a reduced number of price series included are reported only if higher degrees of market integration were found. Results of co-integration tests and tests of the LOP are shown in Table 3.

Table 3: Johansen tests for co-integration and tests of the LOP – Prices of trout and substitutes in Germany

Price series[1]	Model[2]	Johansen test								LOP Tests	
		Eigenvalue				Trace Test[3]				LR	p
		1	2	3	4	P=0	p<=1	p<=2	p<=3		
Frozen T-S-C-M	12	0.72	0.53	0.28	0.13	***148.31	***72.99	***28.04	*8.02	52.20	<0.01
Frozen T-S-C-R	D/6	0.39	0.21	0.25	0.04	***69.18	***44.61	**21.71	2.54	13.05	<0.01
Frozen T-S-C	4	0.23	0.18	0.09	.	**36.95	*19.40	6.14	.	5.43	0.07
Smoked T-H-M	DD/12	0.40	0.24	0.12	.	**54.21	**23.63	7.36	.	5.14	0.08

Notes:

1. T is trout, S is salmon, C is cod, M is mackerel, R is redfish and H is halibut.
2. D = dummy introduced to correct for outlier observations. For frozen redfish 2000.10, 2002.03 and 2003.12, for smoked halibut 1999.10 and 2000.05 and for smoked mackerel 1998.11, 1998.12 and 2000.04. The numbers measure the lags at which the estimations are undertaken.
3. ***/**/* = significance at 1, 5 and 10% levels. Critical values known from Johansen (1996).

In Table 3 the first line represents the test for co-integration between German import prices of frozen trout, salmon, cod and mackerel. A common integrating factor is identified, accepting a 5% significance level (the rank is 3 in the model with four price series). The test of the LOP is, however, rejected. Replacing mackerel by redfish, the second test gives the same result. The German import market for frozen trout, salmon, cod mackerel and redfish are partially integrated. Excluding both mackerel and redfish and thus testing only trout, salmon and cod also identifies a common integrating factor. The rank is 2, although only on the 10% level. Given this rank, the LOP was tested and accepted with p=0.07. This implies that the markets for frozen trout, salmon and cod are perfectly integrated.

The presence of perfect market integration between trout and cod and of partial market integration between trout, redfish and mackerel are as expected, owing to all species being of small size and with white meat. The results point to trout being a part of the European frozen whitefish market where integration is determined by the white color of the meat, the small size of the fish and that these species are considered inferior by German consumers.

The test for co-integration between smoked trout, halibut and mackerel also identify a common integrating factor, with a rank of 2 obtained at the 5% level. The test of the LOP reveals a Likelihood Ratio test statistics of 5.14, corresponding to a p value of 0.08. Thus, the LOP is accepted and the German import market for smoked trout, halibut and mackerel are shown to be perfectly integrated.

The presence of market integration for smoked fish reveals linkages between the trout markets and markets for capture fish. Smoked trout forms part of the same market as halibut and mackerel. Hence, the market for farm-raised trout forms part of the same markets as capture fish. Furthermore, for smoked fish no evidence was found for the two farm-raised species, trout and salmon, being part of the same market. This implies that the smoked trout market is more closely connected to markets for capture fish than for farm-raised salmon, as expected. Reasons for this result include similarities between trout, mackerel and halibut (small white fish) and dissimilarities between trout and salmon (small white and large red, respectively), consumer perception of trout as bulk, that farm-raised trout was an established market 1-2 decades before salmon and that salmon has been subject to continued introduction and subsequent removal of import limitations, minimum import price schemes, safe-guards and anti-dumping duties.

Tests for causality rely on prices and quantities of the aggregated data series being integrated of order one, and that the two data series are co-integrated. Aggregates of price and quantity series were constructed of the goods, which in Table 3 were found to form part of partially integrated markets. The first was of frozen trout, salmon, cod and mackerel. In the second, mackerel was replaced by redfish.

The presence of unit roots was tested for using Augmented Dickey-Fuller tests. The test statistics for the average price levels are –2.81 (12) and –1.81 (12), for the frozen aggregates with mackerel and redfish, respectively. Using first differences of the series the corresponding test statistics are –3.88 (12) and –3.42 (12). Thus, with a 5% critical value of –2.86 (MacKinnon 1991), both price aggregates are integrated of order one. The test statistics for the corresponding quantity levels are –1.52 (12) and –1.86 (12) and using their first differences –3.88 (12) and –3.98 (12). It appears that at the 5% level, both aggregates are integrated of order one. Thus, co-integration tests are only performed for these two aggregates.

Results of the tests for co-integration in demand are shown in Table 4 together with the results of the tests for causality in demand.

Table 4: Johansen tests for co-integration in demand and tests of causality in demand – Aggregates of price and quantities of perfectly integrated markets.

Goods	No. of lags	Johansen test				Weak exogenous Tests			
		Eigenvalue		Trace Test		Price exo		Quantity exo	
		1	2	P=0	p<=1	LR	P	LR	p
Frozen T-S-C-M	6	0.23	0.09	**23.41	6.35	10.57	<0.01	5.33	0.02
Frozen T-S-C-R	7	0.21	0.06	*19.62	4.10	3.21	0.07	10.62	<0.01

The first line represents the test for co-integration between the average price of frozen trout, salmon, cod and mackerel and the total quantity of these goods. A rank of one is identified at the 5% significance level. Thus, the demand system can be identified, and causality in demand is tested through weak exogeniety of the two data series. It appears that neither the price nor the quantity aggregates with LR statistics of 10.57 and 5.33 are weakly exogenous at the 5% level, since the null hypotheses are rejected. Thus, no causal relations can be identified, and no guidelines for the choice of demand system can be given in this case.

The second line of Table 4 represents the test for co-integration between the average price and total quantity of frozen trout, salmon, cod and redfish. A rank of one is found at the 10% level, implying that the demand system can be identified. The null hypothesis of weak exogeneity is, with a LR statistics of 3.21 and a corresponding p value on 0.07, accepted for the price aggregate, but rejected for the quantity aggregate. Again, this is in accordance with a priori expectations and the implication is that consistent estimation of a demand system claims that such system is specified in its ordinary version.

DISCUSSION

The implications of these findings are two-fold, covering economic modelling and policy issues. The implications for economic modelling suggest that a set of pre-tests should be performed before traditional estimation and analysis of demand are carried out. This set includes testing for market integration (Lewbel 1996; Asche, Bremnes and Wessells 1999; Nielsen 2005) combined with the new test for causality in demand. The advantage of testing for market integration is that knowledge of market sizes and boundaries is obtained, and the determination of price elasticities can be based on reliable and consistent statistical basis. The researcher knows which substitutes to include in demand analyses.

The advantage of testing for causality in demand is that the choice of inverse or ordinary demand systems can be based on consistent knowledge of causality. Such knowledge is important, since considerable measurement errors can be incurred if the "wrong" demand system is estimated. Once the direction of causality is established, the researcher knows whether ordinary or inverse demand systems should be estimated.

A priori the causality in demand is expected to depend on the market level and whether the market is supplied from capture fisheries or fish farms. The reason for the supply source being decisive for the direction of causality relates to control. Fish farms can organise their production as they wish and they can choose to sell when the conditions of the markets are favourable. Fishermen do not, to the same extent, have this opportunity, since they have to fish when bio-economy, weather and fisheries management allows. A priori expectations of the superiority of demand systems are shown in Table 5.

Table 5: Guidelines for the choices of the specification of demand systems on fish markets

Market level	Supply source		
	Fisheries	Farms	Both
Ex-vessel and ex-gate	Inverse	Ordinary	Test
Wholesale, export and import	Test	Ordinary	Test
Retail	Ordinary	Ordinary	Ordinary

Besides being dependent on supply source and market level, causality is also dependent on the aggregation level; the higher the level of aggregation, the fewer the number of potential substitutes, and the more reasonable it is to expect the causality to go from quantity to price (inverse demand). Hence, even though the above guidelines can help in the choice between ordinary and inverse demand, ambiguity remains. Thus, the reliability of disaggregated demand analyses of potentially integrated markets will always increase if a pre-test procedure, like the test for causality demonstrated here, is undertaken.

The policy implication of the general finding of few linkages between trout and other fish is that the prices of trout are formed at its own sub-markets, without being severely affected by developments on markets for other fish. This conclusion is obtained for trout as a whole, where sub-markets might include small portion-sized white trout, medium portion-sized red trout and large salmon trout, but since small portion-sized white trout raised in freshwater ponds dominate at the analysed market, conclusions relies only for the part of the trout business operating with freshwater ponds. This implies that income in that industry remains relatively unaffected by prices of other fish species. Thus, the gradual increase in supply of Norwegian salmon in Europe, for example, have had limited effect on income in that part of the trout business. This is also the case for the EU trade measures on salmon, such as minimum price schemes, safe-guards and anti-dumping duties, which also have limited effect on income in the industry. The gain of the industry of such measures on imported salmon is small.

Despite the general finding of relative separate trout markets, some linkages are identified between farmed trout and capture fish like cod, halibut, redfish and mackerel, the reason being that most of these fish are white and sold relatively small, i.e. the consumer's percept trout and these fish as similar. The implication is that if the prices of the capture fish rise, the price of trout follows. Hence, to the extent that fisheries management affects prices of capture fish, the price of trout is also affected. For example, the reduced quotas on cod in the North Sea and the Baltic Sea over the period might have caused a modest upward pressure on the price of trout. The implication is that the part of the trout business operating with freshwater ponds should focus more on developments on captured fish markets than on markets for farmed salmon.

The finding of integration between markets for farmed and captured fish species raise the question of how general the result is. Provided that markets for farm-raised and captured fish are linked, the continued development of aquaculture can reduce the pressure on capture fish stocks, since consumers can choose alternatives among farm-raised fish. Provided that markets are unlinked, however, aquaculture does not affect capture fisheries. The present finding of market integration between trout and capture fish show that aquaculture in some instances reduce the pressure on capture fish stocks, but the finding is only presumed valid for some fish markets, not all, since in several occasions farmed fish are large, where capture fish are small, owing to the heavy exploitation of several fish stocks worldwide.

REFERENCES

Asche F., H. Bremnes, and C. Wessells (1999), Product Aggregation, Market Integration and the Relationships between Prices: An Application to World Salmon Markets, *American Journal of Agricultural Economics*, 81, 568-81.

Asche, F., J. Hartmann, A. Fofana, S. Jaffry, and R. Menezes (2001), *Vertical relationships in the Value Chain: an Analysis Based on Price Information for Cod and Salmon in Europe*, report no. 48/01 from the Centre for Fisheries Economics. Bergen, Norway: Institute for Research in Economics and Business Administration.

Asche, F., A.G. Guttormsen, T. Sebulonsen, and E. Sissener (2005), Competition between farmed and wild salmon: The Japanese Salmon Market. *Agricultural Economics.*

Clay, P. and A. Fofana (1999), *Delineation of the UK Seafood Markets*, SAC Management Division Working Paper no. 3.3, FAIR Project CT96-1814 DEMINT.

Eurofish (2004), *Fish Info Network Market Report on Trout*, August 2004, report available at http://www.eurofish.dk/.

Eurostat (2004), *New Cronos Database*, database available at http://epp.eurostat.cec.eu.int/.

Food and Agricultural Organisation of the United Nations (2002a), *Yearbook of Fishery statistics – aquaculture productions*, Rome.

Food and Agricultural Organisation of the United Nations (2002b), *Yearbook of Fishery statistics – commodities*, Rome.

Food and Resource Economics Institute (2005), Economic Situation of the Danish Fishery 2005, report available at http://www.foi.kvl.dk/.

Girag, S. (2002), An Analysis of the Farmed Trout and Seabream Supply Chains in the Main EU Markets – Denmark, France, Germany, Greece, Italy, Spain and the UK, Report prepared for the EU Commission under the "Perspectives for Plant Protein Use in Aquaculture programme PEPPA, Q5RS-2000-30068.

Gordon D., K. Salvanes, and F. Atkins (1993), A Fish is a Fish is a Fish? Testing for Market Linkages on the Paris Fish Market, *Marine Resource Economics*, 8, 331-43.

Guillotreau, P., ed. (2003a), *Prices and Margins along the European Seafood Value Chain.* EU-Funded Salmar project - Final report. Les Cahiers de l'Artemis- Organisations et Stratégies Industrielles N° 4. Nantes, France: Université de Nantes.

Guillotreau, P. (2003b), How does the European seafood industry stand after the revolution of salmon farming: An economic analysis of fish prices? *Marine Policy* 28:227-233.

Houck, J. P. (1966), The Relationship of Direct Price Flexibilities to Direct Price Elasticities, *Journal of Farm Economics*, 47 (3), 789-92.

Huang, K. S. (1994), A Further Look at Flexibilities and Elasticities, *American Journal of Agricultural Economics*, 76, 313-17.

Ioannidis C, and D. Whitmarsh (1987), Price formation in fisheries, *Marine Policy*, 11, 143-145.

Jaffry, S., S. Pascoe, G. Taylor, and U. Zabala (2000), Price interactions between salmon and wild caught fish species on the Spanish market, *Aquaculture Economics and Management*, 4 (3), 157-67.

Johansen, S. (1996), *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*, Oxford University Press, Oxford.

Johansen, S. and Juselius, K. (1994), Identification of the long-run and the short run structure: An application of the ISLM model, *Journal of Econometrics*, 63, 7-36.

Lewbel, A. (1996), Aggregation without Separability: A Generalized Composite Commodity Theorem, *American Economic Review*, 86, 524-61.

MacKinnon, J. G. (1991), Critical Values for Co-integration Tests, *Long–Run Economic Relationships.* Engle, R. F. & Granger, C. J. F. eds. Pp. 267-76. Oxford. Oxford University Press.

Nielsen, M. (2005), Price Formation and Market Integration on the European First-hand Market for Whitefish, *Marine Resource Economics*, 20, 185-202.

Saarni, K., J. Setälä, A. Honkanen, and J. Virtanen (2003), An overview of salmon trout aquaculture in Finland, *Aquaculture Economics and Management* 7(5-6):335-343.

Steen, F., F. Asche, P. Clay, S. Jaffry, L. Le Grel, S. Pascoe, and M. Tuncel (1999), *The implications for fisheries management systems of interactions between farmed and wild caught species*, SNF report no. 59, final report from the FAIR project CT96-1814, Bergen.

Stigler, G. J. (1969), *The Theory of Price*, London, MacMillan.

Setälä, J., P. Mickwitz, J. Virtanen, A. Honkanen, and K. Saarni. (2002), *The Effect of Trade Liberation to the Salmon Market in Finland*, proceedings of the Eleventh Biennial Conference of the International Institute of Fisheries Economics and Trade, August 19-22 2002, Wellington, New Zealand.

Tuncel M., and L. Le Grel (1999), *Market Delineation of aquatic products in France*, Report no. 4 from the LEN-CORRAIL, University of Nantes.

Virtanen, J., Setälä, J., Saarni, K. and Honkanen, A. (2005), Finnish Salmon Trout-Discriminated in the European Market, *Marine Resource Economics*, 20, 113-119.