

DELINEATION OF FINNISH FISH MARKETS: INTERACTIONS BETWEEN WILD AND FARMED FISH SPECIES

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ABSTRACT

Finnish fish markets have traditionally been supplied by domestic wild fish species: Baltic herring, salmon and several freshwater species. Nowadays, farmed salmon and rainbow trout dominate the market and wild-caught species are moving to niche product segment. In this paper we examine the market integration of Finnish fish markets. We apply multivariate vector autoregressive (VAR) model to study interactions between farmed rainbow trout and wild caught European whitefish, pikeperch, perch and salmon. We found two cointegrated relations in the system. Firstly, European whitefish, pikeperch, and perch are close substitutes to each other. Secondly, we observed co-integration between wild-caught species and farmed rainbow trout. We also modelled the system in moving average form and identified three common stochastic trends, which drive the system. Two of these originate from wild fish species and one comes from farmed rainbow trout. This implies that in the Finnish market wild fish species compete with each other and the prices of these species are affected by farmed fish.

Keywords: Market integration, freshwater fish species, multivariate cointegrated VAR.

INTRODUCTION

Baltic salmon (*Salmo salar*) and freshwater fish species; pikeperch (*Sander lucioperca*), perch (*Perca fluviatilis*) and European whitefish (*Coregonus lavaretus*) have traditionally been important for commercial small-scale fisheries in Finland and they have previously been the main products on the fresh fish market. Today farmed salmon and rainbow trout are the most common bulk products, while freshwater species have become high-valued seasonal niche products.

In this paper we analysed the market integration between wild caught fish species. In earlier studies it has been proven that there exists a global market for salmon where all species of salmon are substitutes, while other seafood products seem not to be a part of the same market (Bjørndal 1990, Bjørndal et al. 1992, Gordon et al. 1993, Steen 1995, Asche et al. 1999, Asche 2001, Asche et al. 1997, Asche et al. 1998, Asche et al. 2002, Asche et al. 2005).

Finnish markets are also integrated with the global salmon market. Several studies (Mickwitz 1996, Asche et al. 2001, Setälä et al. 2003a) have shown that imported farmed Norwegian salmon, domestic farmed rainbow trout and wild Baltic salmon are close substitutes in the Finnish market, and the price of imported salmon determines the price of wild salmon. There are also other studies indicating market integration between farmed and wild salmon species (Asche et al 2005, Setälä et al. 2003), but so far there has not been clear evidence for integration between farmed, red meat, salmonids and wild, white meat, fish markets.

Virtanen et al. (2005) studied price relationships in the Finnish wild fish market. Bivariate tests between wild salmon and several freshwater species were taken and the results gave strong evidence for close relationship between main freshwater species, whitefish, pikeperch and perch. The results concerning salmon were mixed.

While the earlier studies in Finnish wild fish markets were carried out in bivariate framework, in this paper we apply multivariate vector autoregressive (VAR) modelling. Bivariate analysis is appropriate tool to examine if two products are close substitutes, especially whether the law of one price (LOP) holds between them. In such a case multivariate approach does not add value to the analysis. However, if we are interested in more complex interactions, multivariate approach is essential. If all the prices in the system are not in LOP but several prices interact with each other in long run, these relations can be found in multivariate analysis. In a matter of fact, leaving out one variable

from the analysis, one may lose essential information of the system and hence failed to find appropriate interactions Juselius *et al.* 2000).

In this paper we used multivariate cointegration VAR analysis to study interactions in Finnish fish markets. We applied step-by-step approach presented by Juselius (2006). We formulated the VAR model and identified the long-term cointegration relations. In addition, we inverted the VAR-model into a moving average (MA) model to identify the common stochastic trends that drive the system.

DATA DESCRIPTION

In this study our main focus was on the price formation of wild caught fish species in Finland. From the recent study (Virtanen *et al.* 2005) we expected to find a relationship between wild salmon and major freshwater species: European whitefish, pikeperch and perch. On the other hand many earlier studies have indicated that wild salmon is integrated with global salmon markets. Therefore we also included the farmed rainbow trout in our analysis. Rainbow trout is together with imported farmed salmon a dominant species in Finnish fresh fish markets.

For the analysis we used monthly nominal prices paid to Finnish fishermen for salmon, European whitefish, pikeperch, perch and producer price of rainbow trout. The data was collected by the Finnish Game and Fisheries Research Institute and it covered the time period from January 1992 to December 2004. Figures 1 and 2 below describe price series after logarithmic transformation in their levels and first differences. (LWhitef= European Whitefish; Lperch=Perch; LpikeP=Pikeperch; LStr=Rainbow trout; LWSal=Wild Salmon).

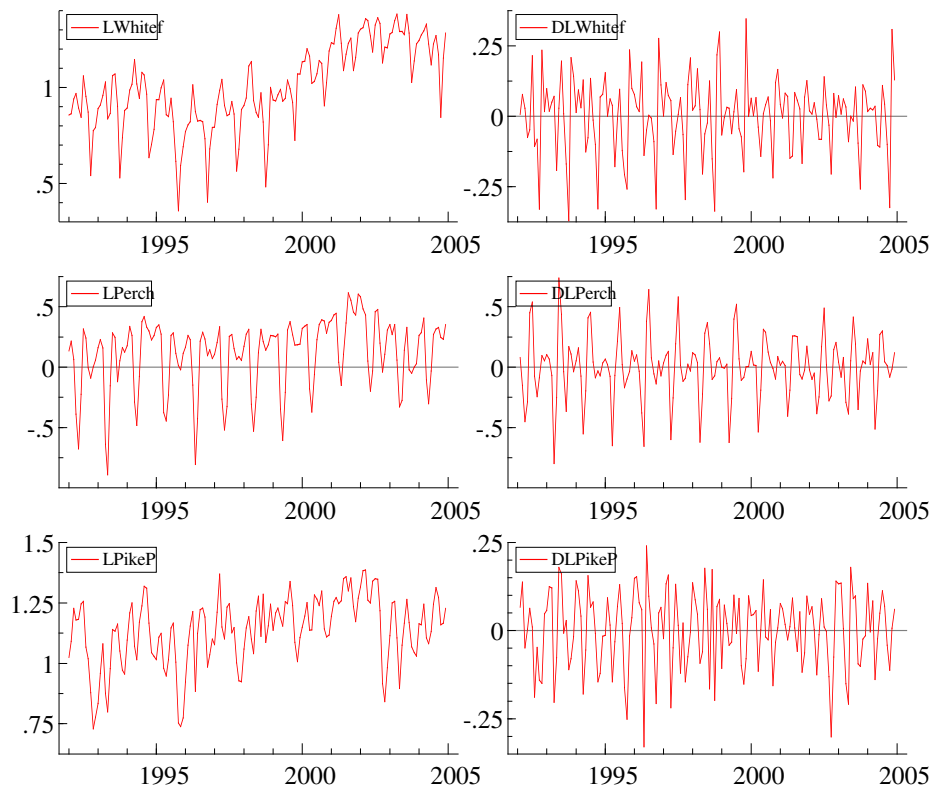


Figure 1. Logarithmic prices series of European whitefish, perch and pikeperch in their levels and first differences.

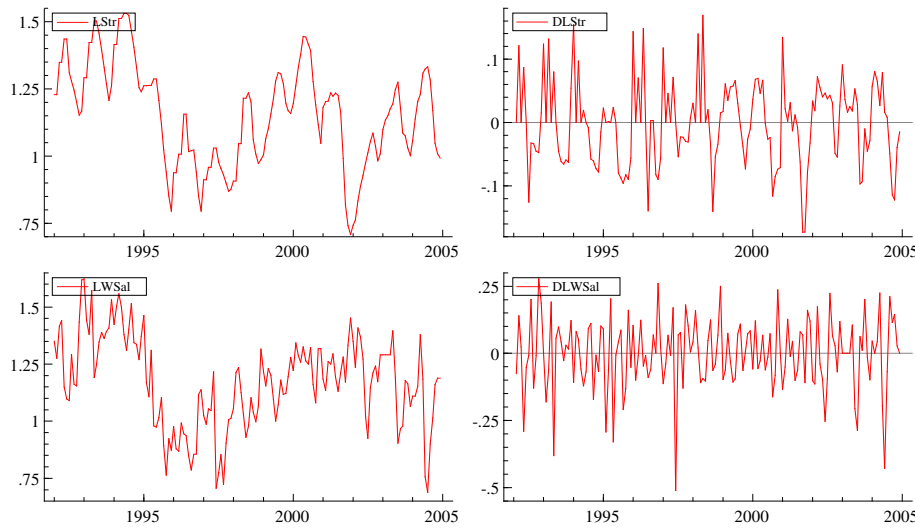


Figure 2. Logarithmic prices series of farmed salmon trout and wild salmon in their levels and first differences.

Price series in general tend to have non-stationary behaviour and large seasonal variation. Thus, it is difficult to conclude whether different species interact with each other. There is no clear trend in the price series. However, in 1995 when Finland joined the EU, food markets were opened for international competition and the fish prices dropped. Especially import of Norwegian farmed salmon increased significantly since then. Consequently prices of salmon and farmed rainbow trout fell drastically. The other species did not react as significantly. Due to this we included dummy variable to our analysis to catch the possible structural brake in the market.

METHODOLOGY

We applied multivariate vector autoregressive modelling to examine market integration and substitution in Finnish fish markets. Vector autoregressive model with k lags, VAR(k), and with deterministic components can be presented as

$$X_t = \mu + \phi_1 X_{t-1} + \dots + \phi_k X_{t-k} + \Psi D_t + u_t \quad (\text{Eq. 1})$$

Where X_t is variable of p prices. D_t is a vector of non-stochastic variables, such as seasonal and intervention dummies, and u_t is a vector of error terms. Price series in general tend to be nonstationary, why they should be analysed in the cointegration framework. The idea of the cointegration analysis is to identify stationary linear combinations between nonstationary variables. Two or more non-stationary series are cointegrated if there exists linear combinations (the so-called cointegration vectors), which are stationary. When cointegration is verified, the variables exhibit stable long-term relationships. The variables may drift apart from another due to random shocks in the short term, but in the long term they will return to their long-term equilibrium (Engle et al. 1991). In this study the economic interpretation is that species are part of the same market if their prices are cointegrated.

VAR model (Eq. 1) can be presented in vector equilibrium-correction (VECM) form:

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

Where $\Gamma_i = -(\mathbf{I} - \phi_1 - \dots - \phi_i)$, ($i = 1, \dots, k-1$), $\Pi = -(\mathbf{I} - \phi_1 - \dots - \phi_k)$. Estimating the VAR model in VECM form serve several advantages. First, multicollinearity effect is significantly reduced in error-correction form. Differences are much more 'orthogonal' than the levels of variables. Secondly, all long-run effects are summarized in the levels matrix Π . In addition, interpretation of estimates straightforward as the coefficient can be classified into short-run and long run effects. (Juselius 2006)

The unrestricted VAR model could be estimated with OLS as stationary process. However if there exists unit roots in the series, the inference is no longer standard (Juselius et al. 2000).

The stability of the process can be studied by calculating the roots of the VAR process. Solving the roots of the companion matrix, we derive eigenvalue roots that are the inverses of the roots of the characteristic polynomial of VAR(k). For VAR(k) with dimension of p we have k*p eigenvalues. Now we have three possibilities:

- If all eigenvalues are inside the unit circle, then the process X_t is stationary.
- If some eigenvalues lie on the unit circle while the others are inside, then the process X_t is non-stationary.
- If any of the eigenvalues are outside the unit circle, then the process is explosive

First, we note that if data is stationary, $x_t \sim I(0)$, the long-run matrix Π is full rank. In a nonstationary VAR model the presence of the unit roots leads to a reduced rank condition in Π . The reduced rank,

$$\text{rank}(\Pi) = r < p, \quad (\text{Eq. 3})$$

(where p is the number of variables) indicates the number of stationary long-term relations, $\beta'x_t$, in the model. Number of unit roots, p-r, gives the number of common driving trends in the system. (Juselius 2006) In this case we can factorise the Π matrix

$$\Pi = \alpha\beta' \quad (\text{Eq. 4})$$

where α and β are p x r matrices. Thus under integration of degree one, I(1) and $0 < r < p$, the cointegrated VAR(k) model (Eq. 2) can be written:

$$\Delta X_t = \mu + \Gamma_1 \Delta X_{t-1} + \dots + \Gamma_{k-1} \Delta X_{t-k+1} + \alpha\beta' X_{t-1} + \Psi D_t + u_t \quad (\text{Eq. 5})$$

where $\beta'x_{t-1}$ is an r x 1 vector of stationary cointegration relations. When $x_t \sim I(1)$, all stochastic components are stationary in (Eq. 5). While β describes the long run stationary relations, α describes the speed of adjustment to the equilibrium.

In summary, if Π is full rank, we have a stationary data. If Π is reduced rank, data is nonstationary and if also the rank of Π is r that is non-zero, we have r stationary cointegrated relations. If the rank of Π is zero, there is no cointegration between data series.

The determination of the cointegration is crucial for the analysis, but not straightforward. The problem is how to discriminate empirically between zero and non-zero eigenvalues that relate to stationarity of the relations. If we underestimate rank r, then we omit relevant equilibrium-correction mechanisms. On the other hand if we overestimate r, the rth cointegration relation would not improve the explanatory power of the model but, instead, would invalidate subsequent inference. (Juselius 2006)

Johansen (1988) proposed a test for r cointegrated vectors based on the maximum likelihood approach: The trace test.

$$LR(H_r \mid H_p) = -T \sum_{i=r+1}^p \ln(1 - \lambda_i), \quad (\text{Eq. 6})$$

where $(\lambda_1, \lambda_2, \dots, \lambda_p)$ are eigenvalues that describes the stationarity of corresponding eigenvectors. The object of the test is to discriminate between the stationary cointegration relations, $\beta' x_{t-1}$, and the nonstationary eigenvectors.

In many cases small-sample distributions for trace test suffer a problem of size and power. Therefore Juselius (2006) and Juselius *et al.* (2000) recommended that the choice of the cointegration rank should be done based on as much information as possible. They suggested following information when deciding on the choice of cointegration rank:

- The trace test
- The recursive graphs of the trace statistic

- The t-values of the α -coefficients for the r th+1 cointegration vector: if these are small, it does not contribute much to model
- The characteristic roots of the model: if the r th+1 cointegration vector is non-stationary and is wrongly included in the model, then the largest characteristic root is close to the unit circle.
- The graphs of the cointegrating relations:
- The economic interpretability of the results.

After we determined the rank of the system according to those guidelines, we started making restrictions to β and α . We performed the exclusion test to confirm that all variable belong to the system. Then we tested the stationarity of the variables with the given rank of Π .

We also tested for weak exogeneity and unit vector in α . Weakly exogenous prices are not adjusting for the long-run parameters β . It defines a common driving trend that are called pushing forces of the system. The test of unit vector in α determines variables that are exclusively adjusting having no permanent effect to other variables.

After these standard hypothesis testing we started identifying the long-run structure. This is an important phase because we should find economic interpretation to our results.

After we have identified the long-term relations of the system we also wanted to identify the common driving trends and how these affected the system. This was done by turning the VAR model in corresponding moving-average (MA) form.

A stationary VAR model can directly be inverted into the MA model. When VAR model contains unit roots, the autoregressive lag polynomial becomes non-invertible. However under the reduced rank assumption we get from VAR the corresponding MA representation (Juselius 2006):

$$x_t = C \sum_{i=1}^t \varepsilon_i + C * (L)\varepsilon_t + \tilde{X}_0 \quad (\text{Eq. 7})$$

The moving average representation describes the process x_t by stochastic trends $C \sum_{i=1}^t \varepsilon_i$, stationary stochastic components $C*(L)\varepsilon_t$ and X_0 contains initial values of the process. In (Eq. 7) we have

$$C = \beta_{\perp} (\alpha'_{\perp} \Gamma \beta_{\perp})^{-1} \alpha'_{\perp} = \tilde{\beta}_{\perp} \alpha'_{\perp} \quad (\text{Eq. 8})$$

where α_{\perp} and β_{\perp} are orthogonal complements of α and β matrices

There exists duality between cointegration and common trends. C matrix in MA representation is similar to Π matrix in VAR form. In VAR β determines the common long-run relations and α the loadings, while in MA α_{\perp} determines the common stochastic trends and $\tilde{\beta}_{\perp}$ their loadings. So from (Eq. 7) and (Eq. 8) we can now identify the p - r common stochastic trends that x_t originates from:

$$\alpha'_{\perp} \sum_{i=1}^t \varepsilon_i \quad (\text{Eq. 9})$$

These cumulated residuals define common driving trends that affect x_t weighted by $\tilde{\beta}_{\perp}$.

RESULTS

First we estimated the unrestricted VAR model in VECM form (Eq. 2) with deterministic components: constant term, seasonal dummies and structural dummy for EU membership. In the model we included five fish species: European whitefish, pikeperch, perch, wild salmon and farmed rainbow trout. The data covered 1992 – 2004. Lag-length of two was chosen based on Schwarz and Hannan-Quinn information criterias.

After including three dummy variables for large residuals the misspecification tests were passed. Only the residuals from the whitefish equation exhibited borderline significant ARCH effects. However, Rahbek et. al (2002) have shown that the cointegration tests are robust against moderate residual ARCH effects.

Table I: Estimated coefficients for the unrestricted model

Long run effects: $\hat{\beta}'_i$							
	LWHITEF	LPIKEP	LPERCH	LWSAL	LSTR	DUMEU	CONSTANT
Beta1	0.509	5.880	-11.439	6.810	-2.194	1.730	-12.733
Beta2	-3.642	-6.356	3.966	9.002	-3.179	2.149	1.871
Beta3	3.192	-9.721	-1.317	-0.921	0.356	0.348	8.501
Beta4	4.226	-1.612	0.103	-0.923	-6.512	-3.149	8.343
Beta5	-3.939	0.557	-0.418	-0.156	-4.362	-0.822	9.522

Adjustment coefficients: $\hat{\alpha}_i$					
	Alpha1	Alpha2	Alpha3	Alpha4	Alpha5
DLWHIT	-0.006	0.001	-0.006	-0.008	0.006
DLPIKE	-0.006	0.005	0.018	-0.004	0.002
DLPERC	0.036	-0.022	0.012	-0.009	0.002
DLWSAL	-0.032	-0.036	0.001	0.001	0.002
DLSTR	0.002	0.002	-0.001	0.008	0.003

The combined effects: $\hat{\Pi}$							
	LWHITEF	LPIKEP	LPERCH	LWSAL	LSTR	DUMEU	CONSTANT
DLWHIT	-0.083	0.032	0.081	-0.023	0.039	0.010	0.016
DLPIKE	0.013	-0.236	0.065	-0.016	0.021	0.015	0.234
DLPERC	0.087	0.254	-0.519	0.050	0.046	0.048	-0.463
DLWSAL	0.115	0.029	0.224	-0.541	0.168	-0.137	0.375
DLSTR	0.014	-0.003	-0.015	0.020	-0.071	-0.020	0.064

The estimated coefficients of the unrestricted model are presented in table I. Statistically significant coefficients are printed bold. The stationarity of the system was studied calculating the roots of the unrestricted VAR process. In our case we have two lags and five price series and thus $2 \times 5 = 10$ eigenvalues. The largest eigenvalues are presented in the table II.

Table II: Five largest eigenvalue roots

	Real	Imaginary	Modulus	Argument
Root1	0.963	-0.000	0.963	-0.000
Root2	0.912	-0.000	0.912	-0.000
Root3	0.796	0.000	0.796	0.000
Root4	0.477	-0.000	0.477	-0.000
Root5	0.070	0.340	0.347	1.367

All roots lied inside the unit circle, thus the system is not explosive. The table shows that there are two or three large roots. These near unit roots indicate non-stationarity in the series and possible cointegration. From α -matrix in table I

we can see that there are three columns with statistically significant non-zero coefficients indicating cointegration. We can also find some indication of long-term relations from the Π -matrix.

To determine the correct cointegration rank we first performed trace test. The trace test for cointegration rank had to be corrected for small sample and also for the structural break for EU membership. The results suggested rank of one at the 5 % significance level and rank of two at the 10 % significance level.

According to Juselius (2006) we used also other information to determine the correct cointegration rank. We studied recursive calculated trace test statistics. The recursive graphs of the trace statistic should show a linear growth in time for stationary relations (Eq. 6). We found that first two increasing, but the other eigenvalue stayed on the borderline of acceptance.

Also like noted before, there were statistically significant α -coefficients (with t-values over 3.0) related to three cointegrated vectors. We also studied the characteristic roots of the model. We found two or three large roots that could indicate unit roots. Graphs of the stationary cointegration relations should show a stationary behaviour around its mean. We noted that two relations were fairly stable while the third one showed clear persistence. This indicated a rank of two.

And at last but not least, Juselius *et al.* (2000) call for economic interpretability of the results. We noted that accepting a rank of three, the third unstable relation would have referred a stationarity of pikeperch. Therefore we chose the rank of two.

After we had chosen the rank and estimated the model with two cointegrating relations, we started to test restrictions to β and α . This is the most important phase in the sense that we want to find an economic interpretation for the results. Table III presents standard test statistics build-in CATS in RATS for a given rank of two.

Table III: LR-test statistics (chi-square, p-values in brackets) for tests of exclusion, stationarity, weak exogeneity and unit vector in alpha

TEST OF EXCLUSION								
r	5% C.V.	LWHITEF	LPIKEP	LPERCH	LWSAL	LSTR	DUMEU	CONSTANT
2	5.991	5.535 (0.063)	13.971 (0.001)	41.745 (0.000)	27.342 (0.000)	7.147 (0.028)	14.585 (0.001)	23.150 (0.000)
TEST OF STATIONARITY								
r	5% C.V.	LWHITEF	LPIKEP	LPERCH	LWSAL	LSTR		
2	7.815	28.343 (0.000)	18.370 (0.000)	18.897 (0.000)	16.790 (0.001)	26.276 (0.000)		
TEST OF WEAK EXOGENEITY								
r	5% C.V.	LWHITEF	LPIKEP	LPERCH	LWSAL	LSTR		
2	5.991	1.677 (0.432)	1.664 (0.435)	23.797 (0.000)	25.106 (0.000)	0.525 (0.769)		
TEST OF UNIT VECTOR IN ALPHA								
r	5% C.V.	LWHITEF	LPIKEP	LPERCH	LWSAL	LSTR		
2	7.815	25.320 (0.000)	15.223 (0.002)	2.720 (0.437)	0.602 (0.896)	27.006 (0.000)		

The exclusion test suggest that European whitefish is in the borderline of being excluded. However, since it is the most important wild freshwater species we preferred to keep it in the system. All other variables, including dummy variable for EU and constant that are restricted on the cointegration space, clearly belong to the system.

The test of stationarity showed that stationarity depends on the rank decision. If we had chosen the rank of three, the test statistics would have indicated pikeperch to be stationary. And also perch would have been in the borderline. In the case of rank of two the data series are nonstationary.

Whitefish, pikeperch and rainbow trout were found weakly exogenous. Perch and wild salmon are endogenous variables in the system. The test of unit vector in alpha indicates that both species are also exclusively adjusting prices.

Now we have confirmed that our empirical model is adequate and describes the data well enough. We have also learned some preliminary information about our model. In our analysis the β matrix is the most important since we want to study the long run relations of the price series. Therefore the identification of long-run structure is important for two reasons. First we need to make β matrix identified i.e. to be able to get standard errors for β_{ij} . Secondly, we want to test some restrictions to make economic interpretation from the analysis.

In identification we usually have some hypothesis based on economic theory that we want to test. We also have information from the estimation carried out. We already noticed that we have two unit vectors in alpha: both endogenous variables, perch and salmon, are exclusively adjusting. These two unit vectors refers to corresponding cointegration relation in Π matrix, since $\Pi = \alpha\beta'$. The first cointegration relation indicated long-term homogeneity within freshwater species. Therefore for we tested homogeneity restriction between these three species:

$$\beta'_1 x_t = p_{perch} - \omega p_{whitefish} - (1 - \omega) p_{pikeperch} \quad (\text{Eq. 10})$$

The second cointegration relation indicated connection with wild salmon and farmed rainbow trout. In this relation there were also significant coefficients with freshwater species, whitefish and perch. Here we put a homogeneity restriction between these species:

$$\beta'_2 x_t = p_{salmon} - \omega_1 p_{whitefish} - \omega_2 p_{strout} - (1 - \omega_1 - \omega_2) p_{perch} \quad (\text{Eq. 11})$$

Table IV: The restricted model

Long run effects: $\hat{\beta}'_i$							
	LWHITEF	LPIKEP	LPERCH	LWSAL	LSTR	DUMEU	CONSTANT
Beta1	-0.230	-0.770	1.000	0.000	0.000	0.000	0.995
Beta2	-0.201	0.000	-0.482	1.000	-0.318	0.250	-0.747

Adjustment coefficients: $\hat{\alpha}_i$		
	Alpha1	Alpha2
DLWHIT	0.059	-0.034
DLPIKE	0.097	-0.005
DLPERC	-0.466	0.053
DLWSAL	-0.037	-0.541
DLSTR	-0.005	0.024

The combined effects: $\hat{\Pi}$							
	LWHITEF	LPIKEP	LPERCH	LWSAL	LSTR	DUMEU	CONSTANT
DLWHIT	-0.007	-0.046	0.076	-0.034	0.011	-0.008	0.084
DLPIKE	-0.021	-0.075	0.099	-0.005	0.002	-0.001	0.100
DLPERC	0.096	0.359	-0.491	0.053	-0.017	0.013	-0.503
DLWSAL	0.117	0.028	0.224	-0.541	0.172	-0.135	0.368
DLSTR	-0.004	0.004	-0.016	0.024	-0.008	0.006	-0.023

The table IV presents the results of estimating the restricted model (Statistically significant coefficients are printed bold). The two homogeneity restrictions were accepted by impressive p-value of 0.998. In the second relation the structural dummy for EU membership was found to be significant. The results confirm the earlier results that the main freshwater species are cointegrated: they have long run homogenous relationship. This means that they share a common stochastic trend. It affects all freshwater species the same way. And thus even though they are not pair-wise homogenous, their markets are integrated and that they are substitutes to each other.

The other cointegration relation is very interesting. We found homogenous relation between wild freshwater species and salmon with farmed rainbow trout. It proves the connection of wild caught fish species and farmed rainbow trout. The earlier studies have suggested that farmed salmon interact with wild caught salmon species, but here we find that farmed rainbow trout also affects prices of wild freshwater species that are very different in they appearance and taste. The only connective factor is that they are all fish species and are marketed in the same manner – fresh fillets.

After we had identified the long-term relations of the system we wanted to identify the common driving trends of the system. This was done by inverting the VAR model in corresponding moving-average (MA) form. The MA representation presented in table IV below identifies the common driving trends in the system (Statistically significant coefficients are printed bold). The system is driven by three common stochastic trends, two of them originating solely from wild species, European whitefish, pikeperch, and one from the farmed rainbow trout. Perch and wild salmon are exclusively adjusting and their price shocks does not have long-term impact to other species.

Table IV: The Moving Average representation.

The Coefficients of the Common Trends: α'_\perp					
	LWHITEF	LPIKEP	LPERCH	LWSAL	LSTR
CT (1)	1.000	0.000	0.131	-0.050	0.000
CT (2)	0.000	0.000	-0.013	0.043	1.000
CT (3)	0.000	1.000	0.207	0.011	0.000

The Loadings to the Common Trends: $\tilde{\beta}_\perp$			
	CT1	CT2	CT3
LWHITE	0.843	0.267	-0.036
LPIKEP	-0.021	0.142	0.806
LPERCH	0.178	0.170	0.613
LWSAL	0.233	0.465	0.268
LSTR	-0.069	1.036	-0.064

The Long-Run Impact Matrix: C					
	LWHITEF	LPIKEP	LPERCH	LWSAL	LSTR
LWHITE	0.843	-0.036	0.100	-0.031	0.267
LPIKEP	-0.021	0.806	0.162	0.016	0.142
LPERCH	0.178	0.613	0.148	0.005	0.170
LWSAL	0.233	0.268	0.080	0.011	0.465
LSTR	-0.069	-0.064	-0.036	0.047	1.036

The loadings of these common stochastic trends are given in Beta orthogonal. The long-run impact matrix C shows that pikeperch and rainbow trout are driven only by the shocks of their own, while whitefish is affected also from the shocks of rainbow trout. Perch is an adjusting price within freshwater fish species that are driven by whitefish and pikeperch trends. Wild salmon is driven by all three common trends. It means that wild salmon price is driven by changes in farmed rainbow trout prices and also changes in pikeperch and whitefish prices.

The results indicate that Finnish wild fish markets are driven by stochastic of it's own that originates from European whitefish and pikeperch but wild species are also affected by shocks from farmed rainbow trout.

CONCLUSION AND DISCUSSION

We have applied the cointegrated VAR modelling to Finnish fish markets. In a multivariate VAR model we included price series of major wild fish species and the market dominating rainbow trout. We estimated the model and found two cointegrated relations. After identifying the long-run relations we inverted the model in moving average form to identify the common stochastic trends that drives the system.

The results were very interesting. We identified two homogenous cointegrated relations in the system that was driven by three common stochastic trends originating from European whitefish, pikeperch and farmed rainbow trout. They are the pushing forces of the system, while wild salmon and perch are purely adjusting variable

The first cointegration relation confirmed the close market integration between wild freshwater species: European whitefish, pikeperch and perch. We found homogenous relation between these species. Secondly, we found homogenous cointegrated relation between wild salmon, European whitefish, perch and farmed rainbow trout. The results indicate that Finnish wild fish markets are driven not only by the stochastic trends of their own, but also by the stochastic trend of farmed rainbow trout. This means that farmed rainbow trout affects the prices of wild caught fish.

The results were achieved applying multivariate approach. It showed that with multivariate analyses we can find interactions that we would fail to detect in bivariate analysis. In this study European whitefish was found to be the link between farmed fish and wild fish market. If we had excluded it from the analysis we would not have found the interaction between wild and farmed fish. Therefore the analysis shows that if we are interested in more complex systems and price formation mechanisms the multivariate analysis is more appropriate approach than bivariate analysis.

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ENDNOTES

* Important feature of reduced rank matrices α and β in (Eq.4) are that they have orthogonal complements α_{\perp} and

β_{\perp} . They are $p \times (p-r)$ matrices and

$$\alpha'_{\perp} \alpha = 0$$

$$\beta'_{\perp} \beta = 0$$

$\alpha\alpha'_{\perp}$ and $\beta\beta'_{\perp}$ have full rank. (Juselius *et al.* 2000)