CAUSALITY AND PRICE TRANSMISSION BETWEEN FISH PRICES: NEW EVIDENCE FROM GREECE AND UK

CHRISTOS FLOROS, UNIVERSITY OF PORTSMOUTH, Christos.Floros@port.ac.uk

ABSTRACT

This paper re-examines the evidence of causality and price transmission between fish prices of main species landed into Piraeus (Greece) and Cornwall (UK). To complete the analysis of cointegration and causality, we use the data of Floros and Failler (2004) and Avdelas (2004). Our paper uses the Bivariate Generalised Autoregressive Conditional Heteroscedastic (BGARCH) model. The Bivariate cointegration model (with GARCH error structure) incorporates a time varying conditional correlation coefficient between fish prices and generates time-varying covariances. The results from BGARCH show evidence of volatility clustering in the change of fish prices, and report that most species lead Hake (this is stronger for Greece). Furthermore, the estimates of price transmission indicate that the rate of change of Shrimp/Dentex partially adjusts to the rate of change of Hake prices. Our results suggest significant imperfect price transmission between species (this is stronger for Greece).

Keywords: Fish prices, price transmission, causality, Cornwall, Piraeus, BGARCH.

INTRODUCTION

This paper analyses price relationships using weekly and monthly data from fisheries. We examine causality and price transmission between top species landed into Piraeus (Greece) and Cornwall (UK). The purpose of this paper is twofold. Firstly, we identify short- and long-run dynamics and causality between fish prices. Secondly, we examine the degree of price transmission across prices. According to Rezitis (2003), the presence of causality implies that markets use information from each other when forming their own price expectations (indicating market integration), while imperfect price transmission alters the welfare of market participants because it causes changes in relative prices. Price volatility examines the relative uncertainty of prices in markets (see Rezitis, 2003; p. 381).

Yet, to our knowledge, there has been a limited research in the past to analyse the price transmission and causality effects. Rezitis (2003) explains the causality and price transmission between Greek producer-consumer meat prices (lamb, beef pork and poultry) using the bivariate Generalized Autoregressive Conditional Heteroscedastic (GARCH) model. The results indicate significant price effects in the markets.

A number of studies investigate the price flexibilities/linkages in the fishing industries of Europe, Japan and U.S (Jaffry *et al*., 1999; Floros and Failler, 2004). Recent papers consider cointegration methods to study the long-run equilibrium between prices and market delineation (Jaffry *et al*.; 1999, Bose and McIlgorm; 1996, Gordon *et al*.; 1993). Recently, Floros and Failler (2004) examine the evidence for seasonal effects and cointegration between fisheries prices of main species landed into Cornwall. The results show significant cointegration (long-run relationship) between prices, and also reveal that Granger causality is unidirectional in fourteen cases and bi-directional in six cases. Avdelas (2004) examines cointegration analysis using data from Greece (Piraeus) covering the period 2000-2003. The results provide little evidence of market segments. There is evidence that all species (except pandora) form part of a system of fish prices, while European hake and Pandora are cointegrated. Furthermore, the maximum eigenvalue test does not reject the null hypothesis on no cointegration between European hake and large eye dentex.

The aim of this paper is to explain the movement of fisheries prices using a new method, the bivariate GARCH (BGARCH) model. We use a BGARCH model because fisheries prices have been associated with varying degrees of volatility (i.e. the conditional variances are not constant). Therefore, it is reasonable to use an appropriate model to capture the behaviour of conditional variance. The paper follows the previous work of Rezitis (2003) and extends the recent works of Floros and Failler (2004) and Avdelas (2004).

The paper is organised as follows: Section 2 describes the data, while Section 3 shows an overview of econometric models employed. Section 4 presents empirical results. Finally, Section 5 concludes the paper and summarizes our findings.

DATA

Cornwall is the most important county in the South West England. The SW fishing industry is estimated to be worth £244 million and accounts for approximately 3,350 jobs. A total of £72.4 million worth of fish was landed in SW ports in 2001. This is equivalent to 0.11% of the GDP of the region. The SW fishing fleet is made up of 1,149 vessels. The main species can be divided into the following groupings: pelagics 7%, prime fish 32%, non-quota shell 33% and medium value fish 28%. Newlyn (the main port in Cornwall), accounts for the great majority (64%) of landings.

The UK data employed in this paper comprise 132 monthly observations on the main species landed into Cornwall covering the period from January 1992 to December 2002. Monthly average prices (£/tonne) for main species were obtained from Defra[1] (UK). We consider the following six species (based on two main fish types): Anglerfish, Cod, Dogfish, Hake, Saithe, Whiting (Demersal fish), and Crabs (Crustacea fish).

Furthermore, the Greek data consist of weekly transactions (quantity and value per species) for the years 2000 to 2003 for the fish landing site based at Piraeus (Keratsini), which is considered the biggest fish market in Greece serving mainly the Metropolitan area of Athens. During the four-year period 95,460,727.77 Kg of 136 species were soled at the Keratsini fish market. While the total quantities sold for 35 species where below one tone, the quantities sold for 20 species are about 82% of the total quantity sold during the four-year period. In this paper species are ranked by their total value of the period and the first nine species where selected. We consider the following species: Hake, Anchovy, Dentex, Pandora, Picarel, Seabass, Seabream, Gilthead and Shrimp. The Greek data is obtained from the database of ETANAL S.A. (www.etanal.gr).

A necessary condition for stable relationship is that each of the variables should be integrated of the same order. The Augmented Dickey-Fuller (ADF) test is performed on both the levels and first differences of the log-series. The results of ADF tests for both markets indicate that each series is nonstationary in levels and stationary in first differences, see Floros and Failler (2004), Floros and Avdelas (2004) and Avdelas (2004). As a result[2], the series are individually integrated of order one, I(1). Therefore, all series are correlated, and regression techniques can be used to confirm whether there exists significant price effects in the markets under consideration.

METHODOLOGY

To derive variances and covariances, we employ BGARCH model accommodating time-varying conditional second moments. BGARCH models have been used to explain causality and price transmission in Greek meat prices, see Rezitis (2003), and in agricultural prices, see Apergis and Rezitis (2003). To the best of our knowledge, this is the first empirical investigation on price transmission and causality effects between fish prices using the method of BGARCH.

In BGARCH modelling, we assume that conditional mean equations are somehow modelled, no details are given now. When the variables are logarithms to the price $Y1_t$ and the logarithms to the price $Y2_t$, we have:

$$Y1_t = Model(Y1_t) + \varepsilon_{Y1,t} \qquad \text{(Eq. 1)}$$

$$Y2_t = Model(Y2_t) + \varepsilon_{Y2,t} \qquad \text{(Eq. 2)}$$

The error terms are then used in the building of conditional variance and covariance equations. In the simplest version, these equations take the form

$$Var(Y1_t) = c_1 + a_1(\varepsilon_{Y1,t-1})^2 + b_1 Var(Y1_{t-1}) \qquad \text{(Eq. 3.1)}$$

$$Var(Y2_t) = c_2 + a_2(\varepsilon_{Y2,t-1})^2 + b_2 Var(Y2_{t-1}) \qquad \text{(Eq. 3.2)}$$

$$Cov(Y1_t, Y2_t) = c_3 + a_3 \varepsilon_{Y1,t-1} \varepsilon_{Y2,t-1} + b_3 Cov(Y1_{t-1}, Y2_{t-1}) \qquad \text{(Eq. 3.3)}$$

In building this model we use nine GARCH parameters plus any parameters from the mean models. Estimation is by maximum likelihood. Considering two species, *S* and *F*. More specifically, we can estimate variances/covariance using weekly/monthly fisheries prices by the following model in log-prices form:

[1] DEFRA stands for Department for Environment Food and Rural Affairs.

[2] The results from ADF tests are available upon request.

$$Y_t^{Y1} = \mu_{Y1S} + \varepsilon_{Y1t}$$
$$Y_t^{Y2} = \mu_{Y2F} + \varepsilon_{Y2Ft} \qquad \text{(Eq. 4)}$$
$$\varepsilon_t \mid \Psi_{t-1} \sim BN(0, H_t)$$

$\varepsilon_t = [\varepsilon_{St}, \varepsilon_{Ft}]'$. The form of H_t for a BGARCH(p,q) model is written as

$$vech(H_t) = vech(C) + \sum_{i=1}^{q} A_i vech(\varepsilon_{t-1}\varepsilon_{t-1}') + \sum_{i=1}^{p} B_i vech(H_{t-1}) \qquad \text{(Eq. 5)}$$

where C is a 2x2 positive definite symmetric matrix and A_i and B_i are 3x3 matrices. However, the parameterisation in eq. (5) is difficult to estimate, since positive definiteness of H_t is not guaranteed. Also, the model contains too many parameters. The *vech* model allows for a very general dynamic structure of the multivariate volatility process. This specification suffers from high dimensionality of the relevant parameter space, which makes it intractable for empirical work. In the diagonal VECH formulation, it is assumed that the conditional variance of the index is not affected by the errors or by the conditional variance of the index, nor by the conditional covariance. A similar assumption is made for the conditional variance of the future. It is also assumed that the conditional covariance is not affected by the conditional variances. For this, 12 extra parameters are required for the full VECH formulation:

$$\begin{bmatrix} Var(\Delta S_t) \\ Cov(\Delta S_t, \Delta F_t) \\ Var(\Delta F_t) \end{bmatrix} = \begin{bmatrix} c_1 \\ c_3 \\ c_2 \end{bmatrix} + A \begin{bmatrix} (\varepsilon_{S,t-1})^2 \\ (\varepsilon_{S,t-1}\varepsilon_{F,t-1}) \\ (\varepsilon_{F,t-1})^2 \end{bmatrix} + B \begin{bmatrix} Var(\Delta S_{t-1}) \\ Cov(\Delta S_{t-1}, \Delta F_{t-1}) \\ Var(\Delta F_{t-1}) \end{bmatrix} \qquad \text{(Eq. 6)}$$

where A and B are 3 x 3 matrices.

The computational burden, introduced by more than doubling the number of parameters to be estimated, is very significant. Moreover, neither the diagonal VECH Bollerslev, Engle, and Wooldridge (1988), nor the full VECH formulation of bivariate GARCH enforce positive definiteness of the covariance matrix. This can be remedied, without using too many parameters, by the *BEKK formulation*, see Engle and Kroner (1995). Positive definiteness is easily guaranteed by the BEKK model (named after Baba, Engle, Kraft, and Kroner (1990)). The generic version of the model is given by

$$H_t = C^T C + A^T E_{t-1} E_{t-1}^T A + B^T H_{t-1} B, \qquad \text{(Eq. 7.0)}$$

$$H_t = \begin{bmatrix} Var(S_t) & Cov(S_t, F_t) \\ Cov(S_t, F_t) & Var(F_t) \end{bmatrix} \qquad \text{(Eq. 7.1)}$$

$$E_t = \begin{bmatrix} \varepsilon_{S,t} \\ \varepsilon_{F,t} \end{bmatrix} \qquad \text{(Eq. 7.2)}$$

and where A, B and C are matrices of parameters:

$$C = \begin{bmatrix} C_{11} & C_{12} \\ 0 & C_{22} \end{bmatrix} \qquad \text{(Eq. 7.3)}$$

The *BEKK parameterisation* requires estimation of only 11 parameters in the conditional-covariance structure, and also, guarantees H_t to be positive definite. Compared to the diagonal model, the BEKK model allows for convenient cross dynamics of conditional variances.

In addition, Bollerslev (1990) introduces another way to simplify H_t. He presented the '*constant-correlation specification*' by assuming that the conditional correlation between ε_{St} and ε_{Ft} is constant over time. He defines H_t as

$$\begin{bmatrix} h_{ss,t}^2 \, h_{sf,t}^2 \\ h_{fs,t}^2 \, h_{ff,t}^2 \end{bmatrix} = \begin{bmatrix} h_{s,t} \, 0 \\ 0 \quad h_{f,t} \end{bmatrix} \begin{bmatrix} 1 \quad \rho_{St} \\ \rho_{St} \, 1 \end{bmatrix} \begin{bmatrix} h_{S,t} \, 0 \\ 0 \quad h_{F,t} \end{bmatrix} \qquad \text{(Eq. 8)}$$

In this case, positive definiteness is assured if $h_{S,t} > 0$ and $h_{F,t} > 0$. The above (constant correlation) model contains only 7 parameters compared to 21 parameters encountered in the full VECH model. Notice that estimation of all multivariate GARCH models above is carried out by using conditional quasi maximum likelihood estimation. The conditional log-likelihood function for a single observation can be written as

$$L_t(\theta) = -(n/2)\log(2\pi) - (1/2)\log(|H_t(\theta)|) - (1/2)\varepsilon_t(\theta)' H_t^{-1}(\theta)\varepsilon_t(\theta) \quad \text{(Eq. 9)}$$

where θ represents a vector of parameters, *n* is the sample size, and *t* is the time index.

EMPIRICAL RESULTS

Our approach, for estimating time-varying covariances, is by employing a restricted version of the bivariate BEKK of Engle and Kroner (1995). The Bivariate cointegration model, with GARCH error structure, BGARCH, incorporates a time varying conditional correlation coefficient between fish prices and generates time-varying covariances. We apply several BGARCH models (not reported in detail) to our data, so we can model the variance of each series. In particular, to account for cointegration, we model the mean equations (first moment) with a bivariate error correction model, see Engle and Granger (1987). In addition, we take into account time-varying variances and covariances, by modelling the second moment with a bivariate GARCH(1,1) model as proposed in Engle and Kroner (1995). For estimation, a BHHH algorithm with the Marquardt correction is used. We also use Akaike's information criterion (AIC) to select the best model (representation). Accordingly, the lower AIC value selects the model with the better fit to the data.

The selected bivariate cointegration GARCH(1,1) distributions of log-specie1 (*s*) and log-specie2 (*f*) with 1 lag in the mean equation are given by:

$$\Delta s_t = a_0 + a_1(s_{t-1} - \gamma f_{t-1}) + a_2 \Delta s_{t-1}^s + a_3 \Delta f_{t-1}^s + \varepsilon_{st}$$
$$\Delta f_t = \beta_0 + \beta_1(s_{t-1} - \gamma f_{t-1}) + \beta_2 \Delta s_{t-1}^f + \beta_3 \Delta f_{t-1}^f + \varepsilon_{ft}$$
$$\varepsilon_t = \begin{bmatrix} \varepsilon_{st} \\ \varepsilon_{ft} \end{bmatrix} | \Psi_{t-1} \sim N(0, H_t) \qquad \text{(Eq. 10)}$$
$$h_{st}^2 = c_s + a_s \varepsilon_{s,t-1}^2 + b_s h_{s,t-1}^2$$
$$h_{ft}^2 = c_f + a_f \varepsilon_{f,t-1}^2 + b_f h_{f,t-1}^2$$

where Ψ_{t-1} is the information at time *t-1*, and $s_{t-1} - \gamma f_{t-1}$ is the error term obtained from the OLS equation $s_t = \delta + \gamma f_t + e_t$, a_1 and β_1 are the adjustment coefficients of s and f respectively, and ε_{st} and ε_{ft} are the residuals of the prices. h_{st}^2 and h_{ft}^2 are the conditional variances of s and f, respectively. The coefficients b_s and b_f capture volatility in s and f, respectively. The sum of $a_s + b_s$ and $a_f + b_f$ measure persistence. If the sum is less than one, then the BGARCH(1,1) is valid, otherwise the volatility is infinite (Rezitis, 2003).

Table I reports the AIC and Log Likelihood (LL) values obtained from several BGARCH (1,1) models, with 1 lag in the mean equation, for Greek and UK fish markets. Correlation coefficients are also reported to show the relationship between series. Most of the species landed into Piraeus have positive correlation coefficients, while the Cornish fish species show negative coefficients.

Table I: AIC, LL values and Correlation coefficients

Market	**Piraeus**		
Species	AIC	Log Likelihood	Correlation coefficient
Hake-Bogue	-2.237164	247.5465	0.342039
Hake-Dentex	-0.984641	117.9103	0.609500
Hake-Anchovy	-1.365048	157.2824	0.147515
Hake-Red Mullet	-2.195733	243.2584	0.264198
Hake-Striped	-1.741415	196.2365	0.005674
Hake-Pandora	-1.968669	219.7572	0.476104
Hake-Octopus	-2.618168	286.9804	0.664993
Hake-Picarel	-1.690026	190.9177	0.682268
Hake-Seabass	-2.821969	308.0738	0.009231
Hake-Gilthead	-4.301753	461.2315	-0.161638
Hake-Bluespotted	-1.293980	149.9269	0.255952
Hake-Shrimp	-0.273180	44.27409	0.666898
Market	**Cornwall**		
Hake-Cod	-0.973220	79.25932	-0.398551
Hake-Anglerfish	-1.7486841	129.6642	-0.279002
Hake-Crabs	-0.975512	79.40826	0.209748
Hake-Dogfish	0.325388	-5.150239	-0.062619
Hake-Haddock	-0.479125	47.14314	-0.583064
Hake-Lemonsole	-1.257937	97.76591	-0.286937
Hake-Mackerel	1.182670	-60.87355	-0.278740
Hake-Plaice	-0.805550	68.36077	-0.215050
Hake- Saithe	-0.293487	35.07664	-0.225911
Hake-Sole	-1.617567	121.1418	-0.458130
Hake-Whiting	-0.446018	44.99118	-0.254558

Notes: AIC and LL stands for Akaike and Log likelihood, respectively. Correlation coefficient between series in logarithm.

The results from BGARCH models are presented in Table II (Piraeus) and Table III (Cornwall). The ARCH coefficients are all positive and significant thus implying volatility clustering both in Cornwall and Piraeus change of fish prices. The ARCH coefficients are also less than unity in all cases. The sign and significance of the covariance parameters indicate significance interaction between the two prices. Furthermore, the coefficient of the error correction term, a_1 , is not positive and significant, indicating that Hake does not lead the fish prices, in both markets. Also, the coefficient of the error correction term in Hake equation, β_1, is positive and significant (in six cases), indicating that the change of other fish prices lead Hake (the hypothesis is stronger for Greece). Hence, the results from BGARCH show evidence of volatility clustering in the change of fish prices, and suggest that most species lead Hake. The variances and covariances obtained from restricted version of Bivariate BEKK (BGARCH (1,1) model), are time-varying, in both the Cornish and Greek markets. Also, variance and covariances are clearly able to recognise the trend in the price changes.

Table II. BGARCH(1,1) model for Piraeus (Greece)

PART A.	Method: Maximum Likelihood (Marquardt)					
Fish Equation	Estimates	Estimates	Estimates	Estimates	Estimates	Estimates
Specie 1 (s):	**Dentex**	**Red Mullet**	**Pandora**	**Gilthead**	**Anchovy**	**Shrimp**
c_s	0.216370*	0.054096*	0.076568*	0.012954*	0.089480	0.294794*
Δs^s_{t-1}	-0.187185*	-0.273047*	-0.378015*	-0.385566*	-0.153007*	-0.26066*
Δf^s_{t-1}	0.308051*	-0.103198*	0.062602	0.008586	0.105464	0.580362*
$s_{t-1} - \gamma f_{t-1}$	-0.138525*	-0.134192*	-0.016080	0.000375	-0.387966*	0.022595
a_0	0.287927	0.099532	-0.014241	0.021634	0.280746*	0.238538
GARCH(s)	0.412815	0.714829*	0.741208*	0.859555*	0.885906	0.515890
ARCH(s)	0.525002*	0.675809*	0.477385*	0.430242*	0.020218	0.296645*
γ	-0.490468	0.494580*	1.063457*	34.86035	-0.106174	6.318731*
Specie 2 (f):	**Hake**	**Hake**	**Hake**	**Hake**	**Hake**	**Hake**
c_f	0.104044*	0.094480*	0.115185*	0.128883*	0.118417	0.120051*
Δs^f_{t-1}	0.085374*	-0.015483	-0.061176	0.078438	0.109219*	0.021429
Δf^f_{t-1}	-0.140574	-0.050607	-0.024007	-0.012764	-0.101037	-0.032496
$s_{t-1} - \gamma f_{t-1}$	-0.059809*	0.184269*	0.177889*	0.004481	-0.067079	0.037321
β_0	0.128730	-0.130020*	0.109262	0.283529*	0.046682	0.389104*
GARCH(f)	0.071652	0.341219	-0.099849	-0.216891	0.000854	0.034837
ARCH(f)	0.522383*	0.306282*	0.383322*	0.407739*	0.485539*	0.335439*

PART B.	Method: Maximum Likelihood (Marquardt)					
Fish Equation	Estimates	Estimates	Estimates	Estimates	Estimates	Estimates
Specie 1 (s):	**Bogue**	**Octopus**	**Seabass**	**Picarel**	**Striped**	**Bluespotted**
c_s	0.049058*	0.072959*	0.057675*	-0.020929	0.052794*	0.073730*
Δs^s_{t-1}	-0.053246	-0.22942*	-0.338673*	-0.150349	-0.40082*	-0.411381*
Δf^s_{t-1}	-0.016112	-0.022689	0.090931	0.146692	-0.19533*	0.356401*
$s_{t-1} - \gamma f_{t-1}$	-0.59483*	-0.16468*	-1.59e-06	-0.18857*	-0.025454	0.004000
a_0	0.148871*	-0.027655	-0.003570	-0.24941*	-0.023069	0.042209
GARCH(s)	0.874902*	0.584009*	0.726266*	0.992125*	0.867685*	0.591464*
ARCH(s)	-0.32648*	0.465756*	0.314375*	0.015357	0.396463*	0.917445*
γ	0.090459	0.910498*	95.16265	1.064404*	1.385979	7.203314
Specie 2 (f):	**Hake**	**Hake**	**Hake**	**Hake**	**Hake**	**Hake**
c_f	0.059804	0.126248*	0.127169*	0.002665	0.129685*	0.141442*
Δs^f_{t-1}	0.157382*	-0.064524	-0.103708	0.064624	-0.090193	-0.087998*
Δf^f_{t-1}	-0.13665*	0.027709	-0.001307	-0.083899	-0.020525	-0.036640
$s_{t-1} - \gamma f_{t-1}$	-0.22451*	0.236373*	0.001448	0.092950*	0.116906*	0.023423
β_0	0.056665	0.043677	0.253614*	0.122607	0.088250	0.266949*
GARCH(f)	0.013294	0.102255	-0.038139	0.516586	-0.148132	-0.020474
ARCH(f)	-0.43109*	0.365480*	0.435987*	0.339666*	-0.40799*	0.259002*

Table III. BGARCH(1,1) model for Cornwall (UK)

PART A.	Method: Maximum Likelihood (Marquardt)					
Fish Equation	Estimates	Estimates	Estimates	Estimates	Estimates	Estimates
Specie 1 (s):	**Cod**	**Crabs**	**Dogfish**	**Haddock**	**Plaice**	**Saithe**
c_s	0.053496*	-0.086105*	0.227640*	0.029845	0.143193*	0.118316*
Δs_{t-1}^{s}	-0.288068*	-0.460545*	-0.126917	-0.344956	0.085667	-0.31056*
Δf_{t-1}^{s}	0.124279	0.057233	0.054125	-0.069562	-0.021961	0.039458
$s_{t-1} - \gamma f_{t-1}$	0.000559	0.002450	-0.560206*	-0.045633	-0.052887	-0.000405
a_0	0.298686	0.390298	3.375754*	-0.118931	-0.056425	-0.230273
GARCH(s)	0.893797*	0.646902*	-0.342477	0.969820*	-0.014825	0.707896*
ARCH(s)	0.292398*	0.671799*	-0.424772	0.174577	0.547915*	0.481220*
γ	67.08001	20.63144	0.065360	1.206482	1.080067	67.43293
Specie 2 (f):	**Hake**	**Hake**	**Hake**	**Hake**	**Hake**	**Hake**
c_f	0.152106*	-0.160209*	0.166523	-5.5e-06	-0.030201	-0.17211*
Δs_{t-1}^{f}	-0.034164	-0.060304	-0.054184	-0.124617	-0.242229*	0.034692
Δf_{t-1}^{f}	0.093517	0.126970	-0.059719	-0.013871	0.039323	0.086803
$s_{t-1} - \gamma f_{t-1}$	0.004427	0.017588	-0.032911	0.095248	0.181562	0.004745
β_0	2.362212**	2.812509*	0.195738	0.247510	0.244275	2.548898*
GARCH(f)	0.550422	0.261959	0.602626	0.999348*	0.955314*	0.430752
ARCH(f)	0.351389**	-0.431586*	0.339776	0.008479	-0.022000	0.432067*

PART B. Method: Maximum Likelihood (Marquardt)					
Fish Equation	Estimates	Estimates	Estimates	Estimates	Estimates
Specie 1 (s):	**Anglerfish**	**Lemonsole**	**Mackerel**	**Sole**	**Whitting**
c_s	0.074960*	-0.006272	0.23215*	0.092748	0.050774
Δs_{t-1}^{s}	-0.372479*	0.003791	0.176551	-0.047378	-0.183344*
Δf_{t-1}^{s}	0.054604	-0.000359	-0.11593	-0.099975*	0.021435
$s_{t-1} - \gamma f_{t-1}$	0.001014	-0.003304	0.089149	-0.034736	0.095201
a_0	0.351751	0.006158	0.203919	0.006318	0.375898
GARCH(s)	0.598515*	0.993409*	0.57862*	0.477592	0.945116*
ARCH(s)	0.359555*	0.002182	-0.35313*	-0.009414	0.176611
γ	43.91714	1.068943	1.019082	1.082517	1.293940
Specie 2 (f):	**Hake**	**Hake**	**Hake**	**Hake**	**Hake**
c_f	0.173696	-0.000169	6.79e-05	0.020414	0.000174
Δs_{t-1}^{f}	-0.138659	-0.020007	-0.20200	-0.216023	-0.113236
Δf_{t-1}^{f}	0.094451	-0.006208	-0.07834	0.030755	0.065660
$s_{t-1} - \gamma f_{t-1}$	0.007000	0.132557	0.23601*	0.185714	0.208601
β_0	2.426303	0.064595	0.548023	-0.011591	0.822607
GARCH(f)	0.477840	0.999678*	0.99439*	0.995227*	0.998261*
ARCH(f)	0.271486	0.014223	-0.08908	-1.22e-05	-0.022009

* Significant at 5% level.

Furthermore, we estimate the price transmission (impact) between prices following the study by Rezitis (2003). The price transmission is estimated as follows: from specie1 to specie2 prices, $a_3/(1-a_2)$, while from specie2 to specie1 as $\beta_2/(1-\beta_3)$. The results are reported[3] in Table IV. The impact is stronger for Piraeus, where the price transmission for Shrimp-Hake is 46%, while for Dentex-Hake is 26%. For Cornwall, the estimated impact varies from 9.6% to 3% only, which is not high significant (i.e. the impact is low). So, the estimates of price transmission for Greece indicate that the rate of change of Shrimp/Dentex partially adjusts to the rate of change of Hake prices. These results suggest significant imperfect price transmission between fish markets in Greece only.

Table IV. Price transmission

Market	**Piraeus**
Species	Estimated Impact
Hake-Dentex	0.07485
Dentex-Hake	0.25948
Hake-Anchovy	0.09919
Anchovy-Hake	0.09146
Pandora-Hake	0.04542
Hake-Shrimp	0.02075
Shrimp-Hake	0.46036
Market	**Cornwall**
Cod-Hake	0.09648
Crabs-Hake	0.03918
Dogfish-Hake	0.04802
Hake- Saithe	0.03799
Saithe-Hake	0.03010

Notes: We report positive, different from zero, price transmission estimates.

CONCLUSION

This paper analyses price relationships using weekly and monthly data from fisheries. We re-examine causality and price transmission between top species landed into Piraeus (Greece) and Cornwall (UK). The purpose of this paper is twofold. Firstly, we identify short- and long-run dynamics and causality between fish prices. Secondly, we examine the degree of price transmission across prices. We explain the movement of fisheries prices using a new method, the bivariate GARCH (BGARCH) model. We use a BGARCH model because fisheries prices have been associated with varying degrees of volatility (i.e. the conditional variances are not constant). The results from BGARCH show evidence of volatility clustering in the change of fish prices, and report that most species lead Hake (this is stronger for Greece). Furthermore, the estimates of price transmission indicate that the rate of change of Shrimp/Dentex partially adjusts to the rate of change of Hake prices. Our results suggest significant imperfect price transmission between species (this is stronger for Greece).

Future research should investigate causality, price transmission and volatility spillover effects between fresh and frozen prices in fisheries markets in Europe, using the methodology of BGARCH.

REFERENCES

Apergis, N. and A. Rezitis, 2003, Agricultural price volatility spillover effects: the case of Greece, *European Review of Agricultural Economics*, 30, pp. 389-406.

Avdelas, L. 2004, Quantitative analysis of fisheries prices in Greece, *MSc Dissertation*, *University of Portsmouth*, 106 p.

[3] Table IV reports the estimates of price transmission (impact) between prices that are positive and different from zero.

Baba, Y., R. F. Engle, D. F. Kraft and K. F. Kroner, 1990, Multivariate Simultaneous Generalized ARCH, *mimeo, Department of Economics, University of California, San Diego, CA.*

Bollerslev, T. 1990, Modelling the coherence in short-run nominal exchange rates: a multivariate generalized ARCH model, *Review of Economics and Statistics*, 72, pp. 498–505.

Bollerslev, T., R. F. Engle and J. M. Wooldridge, 1988, A capital asset pricing model with time-varying covariances, *Journal of Political Economy*, 96, pp. 116–31.

Bose, S., and A. McIlgorm, 1996, Substitutability among species in the Japanese tuna market: A cointegration analysis, *Marine Resource Economics*, 11, pp. 143-155.

Engle, R. F. and C. W. J. Granger, 1987, Cointegration and error correction: representation, estimation and testing, *Econometrica*, 55, pp. 251-276.

Engle, R. F., and K. F. Kroner, 1995, Multivariate simultaneous generalized ARCH, *Econometric Theory*, 11, pp. 122-150.

Floros, C., and L. Avdelas, 2004, Seasonality in Fisheries Prices: The Case of Greece, *Paper presented at AquaMedit 2004*, 18-19 June 2004, Athens, Greece.

Floros, C., and P. Failler, 2004, Seasonality and Cointegration in the Fishing Industry of Cornwall. *International Journal of Applied Econometrics and Quantitative Studies*, 1-4, pp. 27-52.

Gordon, D.V., K.G. Salvanes, and F. Atkins, 1993, A fish is a fish? Testing for market linkages on the Paris fish market, *Marine Resource Economics*, 8, pp. 331-343.

Jaffry, S., S. Pascoe, and C. Robinson, 1999, Long run price flexibilities for high valued UK fish species: a cointegration systems approach, *Applied Economics*, 31, pp. 473-481.

Rezitis, A. 2003, Mean and volatility spillover effects in Greek producer-consumer meat prices, *Applied Economics Letters*, 10, pp. 381-384.