Volatility Spillover Effects in Greek Consumer Meat Prices

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Abstract
This paper investigates volatility spillover effects, i.e. 'meteor showers' and 'heat waves', across consumer meat prices for lamb, beef, pork, and poultry. The empirical analysis used the methodology of the Generalized Autoregressive Conditional Heteroskedastic (GARCH) approach. The empirical results support the presence of significant 'meteor shower' and 'heat wave' effects across the four meat categories under consideration.

Keywords: *consumer meat prices, cointegration, volatility spillovers.*
JEL classification: Q11; Q13

Introduction

Price linkages among retail food markets are of considerable economic interest. This paper analyses the consumer price relationships of four different meat categories in Greece: lamb, beef, pork, and poultry markets. Specifically, the purpose of this paper is to investigate volatility spillover effects, as for i.e. the 'meteor showers' and the 'heat waves' effects, across consumer prices for each meat category under consideration. The existence of significant price volatility spillover effects, i.e. of 'meteor showers', implies that price uncertainty in a market, affects price uncertainty on the others, while the existence of significant price volatility in a market, i.e. of 'heat waves', suggests the presence of significant price uncertainty in the specific market.

Price volatility is an estimate of the range within which prices might vary in the future (Weaver and Natcher, 2000). An increase in price volatility implies higher uncertainty about the future prices, because the range in which prices might decrease in the future becomes wider. As a result, both producers and consumers can be affected by increased price volatility since it augments the level of uncertainty and of risk in the market. More specifically, increased price volatility can impede agricultural commodities' producers and consumers to correctly forecast the future prices. Thus, decisions under such circumstances may be unprofitable in the future, if the future prices were not correctly anticipated, causing detrimental effects on the welfare of both producers and consumers of agricultural commodities (Binswanger and Rosenzweing, 1986; Saha and Delgado, 1989). Therefore, it is crucial for both, producers and consumers, to be aware of the degree of price volatility, in order for them to be able to adopt appropriate hedging strategies. The studies by Arabhyula

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and Holt (1988), Kesavan et. al. (1992), and Shively (1996) are examples of studies investigating the degree of price volatility in farm output and retail food markets.

Consumer meat prices are used in this paper because they have been associated with the varying degree of volatility over the past twenty years. Varying degree of inflation rates in the nonfarm economy, large shocks in the price of feed grains, high competition from other European Union (EU) countries, and recent changes of the Common Agricultural Policy (CAP) resulted in volatile meat prices during the 1990s and late 1980s. Thus, it is reasonable to believe that the conditional variances associated with meat prices would not have remained constant during this period, and as a result an appropriate model should allow the conditional variance to reflect this sort of behavior. The methodology followed in this paper to measure volatility spillovers is the one of Generalized Autoregressive Conditional Heteroskedastic (GARCH) models, introduced by Bollerslev (1986). Chou (1988) argued in favor of GARCH models on the grounds that they were capable of capturing various dynamic structures of conditional variance, of incorporating heteroskedasticity with the estimation under examination procedure, and of allowing simultaneous estimation of several under examination parameters. The remaining of this paper is organized as follows: Section 2 describes the methodology employed. Section 3 presents the empirical analysis and discusses the empirical results. Finally, section 4 concludes the paper.

The methodology of the GARCH models

The Autoregressive Conditional Heteroskedastic (ARCH) methodology pioneered by Engle (1978) suggests a method for measuring uncertainty, in case uncertainty is serially correlated. The empirical methodology employed here extends the ARCH model. Let ξ_t be a model's prediction error, $\boldsymbol{a}$ be a vector of parameters, $\mathbf{x_t}$ be a vector of predetermined explanatory variables in the equation for the conditional mean:

$$\boldsymbol{y_t} = \boldsymbol{x_t}\, \boldsymbol{a} + \xi_t \qquad \xi_t|\Omega_{t-1} \sim \mathrm{N}(0, h_t)$$

where h_t is the variance of ξ_t, given information Ω at time $t\text{-}1$. The GARCH specification, as was developed by Bollerslev (1986), defines h_t as:

$$h_t = b_0 + \sum_{i=1}^{p} b_{1i}\, \xi_{t-i}^2 + \sum_{j=1}^{p} b_{2j}\, h_{t-i}$$

with b_0, b_1, and b_2 being nonnegative parameters. According to the above equation, the conditional variance h_t is specified as a linear function of the lagged p squared residuals and its own lagged q conditional variances. Bollerslev (1986) has argued that if $\Sigma b_{1i}+\Sigma b_{2j} = 1$, then the GARCH specification turns into an integrated GARCH (IGARCH) process, implying that current shocks persist indefinitely in conditioning the future variance. Maximum likelihood techniques are used to estimate the parameters of the GARCH model according to the BHHH algorithm (Berndt *et al*., 1974).

Empirical analysis

Data

Monthly data on consumer prices for beef, pork, lamb, and poultry, are obtained from the National Statistical Service of Greece. Specifically, consumer prices for lamb, beef, pork, and poultry are the corresponding consumer price indexes (1990=100) for each meat category, respectively. The sample contains 156 observations running from January 1988 to December 2000. In this paper, p^l, p^b, p^p, and p^c, corresponds to the natural logarithms of consumer prices for lamb, beef, pork, and poultry, respectively. Descriptive statistics for consumer prices for each meat category are reported in Table 1. The sample skewness and kurtosis coefficients indicate that all price distributions are negatively skewed but they are not leptokurtic relative to the normal distribution. The Jarque-Bera tests reject normality at any level of statistical significance, in all cases. The Ljung-Box statistics for 12 lags applied to prices, i.e. LB(12), and squared prices, i.e. $LB^2(12)$, and indicate the presence of significant linear and nonlinear dependencies. Linear dependencies may be due to some degree of market inefficiency. GARCH models can capture nonlinear dependencies (Bollerslev, 1986).

Table 1. Descriptive Statistics

	lamb prices- p^l	beef prices- p^b	pork prices- p^p	poultry prices- p^c
Mean	4.54	4.45	4.58	4.45
Variance	0.06	0.11	0.08	0.09
Skewness	-0.77 [0.00]	-1.01 [0.00]	-0.85 [0.00]	-1.05 [0.00]
Kurtosis	-0.40 [0.32]	-0.22 [0.58]	-0.09 [0.82]	-0.16 [0.69]
J-B	17.50 [0.00]	27.15 [0.0]	18.89 [0.0]	28.99 [0.00]
LB(12)	371 [0.00]	424 [0.00]	388 [0.00]	428 [0.00]
$LB^2(12)$	386 [0.00]	446 [0.00]	413 [0.00]	453 [0.00]

LB is the Ljung-Box statistic for serial correlation. J-B is the Jarque-Bera test for normality. Figures in brackets denote p-values.

Integration analysis

We first run a test for unit root nonstationarity by using unit root tests proposed by Dickey and Fuller (1981). The results related to unit root tests are reported in Table 2. The hypothesis that the variables contain a unit root cannot be rejected at the 5% significant level. When first differences are used, unit root nonstationarity is rejected at the 5% significant level, suggesting that the all variables are I(1). This result creates the possibility of cointegration among producer-consumer prices for each meat category.

Cointegration and error correction analysis: building mean equations

Once having identified that consumer prices are integrated of the same order, i.e. I(1), a vector autoregression VAR model is postulated to obtain a long-run relationship. Tests, developed by Johansen and Juselius (1990), revealed evidence in favor of cointegration, in each meat category. The results are reported in Table 3. Both maximum eigenvalue (λ_{max}) test statistic and trace (λ_{trace}) test statistic indicate that a single long-run relationship exists between consumer prices. Once the presence of a cointegrating relationship was established between consumer prices, the associated error correction vector autoregressive (ECVAR) mechanism, which describes the short-run dynamics, was estimated. The ECVAR model proxied the mean equations for the GARCH process.

Table 2. Augmented Dickey-Fuller unit-root tests

	Without trend		*With trend*	
	Level	*First differ.*	*Level*	*First differ.*
Lamb consumer price (p^l)	-2.170(3)	-6.698(4)*	-2.792(3)	-6.235(5)*
Beef consumer price (p^b)	-2.612(6)	-3.268(5)*	-2.830(6)	-4.746(5)*
Pork consumer price (p^p)	-2.028(9)	-3.751(6)*	-3.197(6)	-3.759(7)*
Poultry consumer price (p^c)	-2.078(12)	-4.241(9)*	-.457(12)	-4.032(9)*

The critical values at 5% are: τ_μ=-2.878 and τ_τ=-3.437. Figures in parentheses denote number of lags in the augmented term that ensures white-noise residuals.

*denotes significance at the 5% level

Table 3. Maximum likelihood cointegration test

Null Hypothesis	*Alternative* Hypothesis		*Critical value 95%*
λ_{trace} rank tests	λ_{trace} rank value		
r = 0	r ≥ 1	74.906	53.480
r ≤ 1	r ≥ 2	29.047	34.870
r ≤ 2	r ≥ 3	9.341	20.180
r ≤ 3	r ≥ 4	3.781	9.160
λ_{max} rank tests	λ_{max} rank value		
r = 0	r = 1	45.859	25.800
r ≤ 1	r = 2	16.705	19.860
r ≤ 2	r = 3	5.561	13.810
r ≤ 3	r = 4	3.781	7.530

Estimates of the GARCH model: causality, price transmission and volatility spillovers

Through the Box-Jenkins methodological procedure, a joint multivariate dynamic GARCH(1,1) model for consumer prices exhibited the best fit. To this end, the following multivariate GARCH(1,1) model was used to examine whether the price volatility of one meat category affects and is affected by the price volatility of the other meat categories:

$$\Delta p_t^l = a_0 + \sum_i \mathrm{a}_{1i}\, \Delta p_{t-1}^l + \sum_i \mathrm{a}_{2i}\, \Delta p_{t-1}^b + \sum_i \mathrm{a}_{3i}\, \Delta p_{t-i}^p + \sum_i \mathrm{a}_{4i}\, \Delta p_{t-1}^c + \varphi_1 u_{t\text{-}1} + \varepsilon_t^l \quad (1)$$

$\varepsilon^l_t \sim \mathrm{N}(0, h^l_t)$

$$\Delta p_t^b = b_0 + \sum_i b_{1i}\, \Delta p_{t-i}^b + \sum_i b_{2i}\, \Delta p_{t-1}^l + \sum_i b_{3i}\, \Delta p_{t-i}^p + \sum_i b_{4i}\, \Delta p_{t-1}^c + \varphi_2 u_{t\text{-}1} + \varepsilon_t^b \quad (2)$$

$\varepsilon^b_t \sim \mathrm{N}(0, h^b_t)$

$$\Delta p_t^b = c_0 + \sum_i c_{1i}\, \Delta p_{t-i}^p + \sum_i c_{2i}\, \Delta p_{t-1}^l + \sum_i c_{3i}\, \Delta p_{t-i}^b + \sum_i c_{4i}\, \Delta p_{t-1}^c + \varphi_3 u_{t\text{-}1} + \varepsilon_t^p \quad (3)$$

$\varepsilon^p_t \sim \mathrm{N}(0, h^p_t)$

$$\Delta p_t^c = d_0 + \sum_i d_{1i}\, \Delta p_{t-i}^c + \sum_i d_{2i}\, \Delta p_{t-1}^l + \sum_i d_{3i}\, \Delta p_{t-i}^b + \sum_i d_{4i}\, \Delta p_{t-1}^p + \varphi_4 u_{t\text{-}1} + \varepsilon_t^c \quad (4)$$

$\varepsilon^c_t \sim \mathrm{N}(0, h^c_t)$

$$h^l_t = \mathrm{k}_0 + \mathrm{k}_1\, \varepsilon^l_{t-1}{}^2 + \mathrm{k}_2\, h^l_{t-1} + \mathrm{k}_3\, h^b_{t-1} + \mathrm{k}_4\, h^p_{t-1} + \mathrm{k}_5\, h^c_{t-1} \quad (5)$$

$$h^b_t = \mathrm{m}_0 + \mathrm{m}_1\, \varepsilon^b_{t-1}{}^2 + \mathrm{m}_2\, h^b_{t-1} + \mathrm{m}_3\, h^l_{t-1} + \mathrm{m}_4\, h^p_{t-1} + \mathrm{m}_5\, h^c_{t-1} \quad (6)$$

$$h^p_t = \mathrm{n}_0 + \mathrm{n}_1\, \varepsilon^p_{t-1}{}^2 + \mathrm{n}_2\, h^p_{t-1} + \mathrm{n}_3\, h^l_{t-1} + \mathrm{n}_4\, h^b_{t-1} + \mathrm{n}_5\, h^c_{t-1} \quad (7)$$

$$h^c_t = \mathrm{r}_0 + \mathrm{r}_1\, \varepsilon^c_{t-1}{}^2 + \mathrm{r}_2\, h^c_{t-1} + \mathrm{r}_3\, h^l_{t-1} + \mathrm{r}_4\, h^b_{t-1} + \mathrm{r}_5\, h^p_{t-1} \quad (8)$$

where Δp^l_t, Δp^b_t, Δp^p_t, and Δp^c_t correspond to the first differences of consumer prices for lamb, beef, pork, and poultry. φ_1 φ_2, φ_3, and φ_4 are the adjustment coefficients of consumer prices for lamb, beef, pork and poultry respectively, and the u_{t-1} is the lagged value of the error correction term deriving from the long-run cointegrating relationship between the four consumer prices. ε^l, ε^b, ε^p, and ε^c are the residuals of the mean process of consumer prices for lamb, beef, pork, and poultry respectively. h^l, h^b, h^p, and h^c are the conditional variances of consumer prices for lamb, beef, pork, and poultry respectively. Focusing on the equations of conditional variances (5)-(8), the coefficient k_2, m_2, n_2, and r_2, capture volatility of consumer prices for lamb, beef, pork, and poultry respectively, i.e. the 'heat wave' effect. By contrast, in equation (5) coefficients k_3, k_4, and k_5 capture volatility spillover effects from beef, pork, and poultry prices to lamb prices respectively, i.e. the 'meteor showers' effects. Furthermore, in equation (6), coefficients m_3, m_4, and m_5 capture volatility spillover effects from lamb, pork, and poultry prices to beef prices respectively. In equation (7) coefficients n_3, n_4, and n_5 capture volatility spillover effects from lamb, beef, and poultry prices to pork prices respectively. Finally, in equation (8) coefficients r_3, r_4, and r_5 capture volatility spillover effects from lamb, beef, and pork prices to poultry prices respectively. The persistence measurements, i.e. the sums of $k_1+k_2+k_3+k_4+k_5$, $m_1+m_2+m_3+m_4+m_5$, $n_1+n_2+n_3+n_4+n_5$ and $r_1+r_2+r_3+r_4+r_5$, measure persistence. If each sum is less than one, then the GARCH model is valid; on the contrary, if one sum equals one then the volatility is infinite. Assuming conditional normality, the model was jointly estimated by maximizing the following log-likelihood function:

$$L(\Theta) = -1/2 \sum_{t=1}^{T} (\ln|\mathbf{W_t}| + \mathbf{e_t}'\mathbf{W_{t-1}}\mathbf{e_t})$$

where **Θ** is the parameter vector of the model to be estimated, T is the number of observations, **e** is the 1x4 vector of residuals, and **W** is the 4x4 conditional variance-covariance matrix.

The estimated results of the multivariate GARCH(1,1) model, which apply to the price equations (1)-(8), are reported in Tables 4. The Ljung-Box statistics, i.e. LB(12) and $LB^2(12)$, indicate evidence against time-varying dependencies and in favor of the multivariate GARCH(1,1) model apply to consumer prices. The results show that the error correcting coefficients, i.e. the φs, are negative and statistically significant, implying that there is significant feedback between the consumer prices. Thus, each one of the retail meat markets uses information from the others when forming its own price expectations. Furthermore, the statistical results show that all the estimated coefficients of the conditional variance equations (5)-(8), i.e. the ks, ms, ns, and rs, are statistically significant at the five percent (5%) level of significance, indicating the presence of significant 'heat wave' and 'meteor shower' effects in consumer meat prices. The persistent measurements are less than one, indicating that the estimated GARCH model is stationary.

Conclusions

The present study investigated volatility spillover effects, i.e. 'meteor showers' and 'heat waves', across four consumer meat categories, i.e. lamb, beef, pork, and poultry. For the empirical analysis the methodology of the GARCH models was used. The empirical findings showed the presence of significant feedback between the four consumer meat prices under consideration, indicating that each one of the retail meat markets uses information from the others when forming their own price expectations. In addition, the statistical results showed the presence of significant volatility spillover effects across consumer meat prices, i.e. significant 'meteor shower' and 'heat waves' effects. The presence of positive and significant price volatility spillover effects across meat markets indicates that higher price volatility in one meat category increases price volatility in the others, rendering meat prices more volatile and thus augmenting market uncertainty and risk for the participants in meat markets.

Table 4. Maximum Likelihood Estimates of the Multiariate GARCH Model for Meat

p^l - lamb equation		p^b - beef equation		p^p – pork equation		p^c – poultry equation	
Coef.	*Estimates*	*Coef.*	*Estimates*	*Coef.*	*Estimates*	*Coef.*	*Estimates*
a_{11}	0.1684	b_{11}	0.2826	c_{11}	0.2262	d_{11}	-0.1323
	(0.0481)*		(0.0948)*		(0.0751)*		(0.0558)*
a_{12}	0.1368	b_{12}	0.0419	c_{12}	0.1801	d_{12}	0.0102
	(0.0441)*		(0.0144)*		(0.0208)*		(0.0032)*
a_{13}	0.1011	b_{13}	-0.0981	c_{13}	-0.0187	d_{13}	0.3670
	(0.0348)*		(0.0327)*		(0.0058)*		(0.1129)*

p^l - lamb equation		p^b - beef equation		p^p – pork equation		p^c – poultry equation	
Coef.	*Estimates*	*Coef.*	*Estimates*	*Coef.*	*Estimates*	*Coef.*	*Estimates*
a_{21}	-0.1215	b_{21}	0.0581	c_{21}	0.0512	d_{21}	0.0623
	(0.0486)*		(0.0215)*		(0.0216)*		(0.0250)*
a_{22}	0.0904	b_{22}	-0.0191	c_{22}	0.0062	d_{22}	0.0900
	(0.0301)*		(0.0063)*		(0.0019)*		(0.0275)*
a_{23}	0.1086	b_{23}	-0.0277	c_{23}	0.0351	d_{23}	0.0330
	(0.0272)*		(0.0132)*		(0.0163)*		(0.0111)*
a_{31}	0.2198	b_{31}	0.1197	c_{31}	0.0021	d_{31}	0.0901
	(0.0751)*		(0.0413)*		(0.0008)*		(0.0244)*
a_{32}	0.0732	b_{32}	-0.0549	c_{32}	0.3682	d_{32}	-0.0673
	(0.0261)*		(0.0311)*		(0.1554)*		(0.0209)*
a_{33}	0.0768	b_{33}	0.0071	c_{33}	0.0236	d_{33}	0.0225
	(0.0129)*		(0.0028)*		(0.0099)*		(0.0095)*
a_{41}	-0.0851	b_{41}	-0.0163	c_{41}	0.0182	d_{41}	-0.0496
	(0.0281)*		(0.0084)*		(0.0076)*		(0.0152)*
a_{42}	0.0762	b_{42}	-0.0173	c_{42}	0.0210	d_{42}	0.0304
	(0.0218)*		(0.0057)*		(0.0098)*		(0.0118)*
a_{43}	0.0150	b_{43}	0.1261	c_{43}	0.0760	d_{43}	0.0988
	(0.00481)*		(0.0469)*		(0.0321)*		(0.0367)*
φ_1	-0.0654	φ_2	-0.0376	φ_3	-0.0104	φ_4	-0.438
	(0.0481)*		(0.0108)*		(0.0032)*		(0.1634)*
k_0	0.0008	m_0	0.0006	n_0	0.0004	r_0	0.0001
	(0.00034)*		(0.0002)*		(0.00002)*		(0.00003)*
k_1	0.0144	m_1	0.0299	n_1	0.0139	r_1	0.0449
	(0.0055)*		(0.0075)*		(0.0041)*		(0.0121)*
k_2	0.0921	m_2	0.0591	n_2	0.0790	r_2	0.0632
	(0.0481)*		(0.0181)*		(0.0197)*		(0.0129)*
k_3	0.0751	m_3	0.0375	n_3	0.0592	r_3	0.0129
	(0.0372)*		(0.0117)*		(0.0137)*		(0.0039)*
k_4	0.0893	m_4	0.0165	n_4	0.0675	r_4	0.0236
	(0.0297)*		(0.0062)*		(0.017)*		(0.0099)*
k_5	0.0784	m_5	0.0511	m_5	0.0429	r_5	0.0489
	(0.0304)*		(0.0162)*		(0.0144)*		(0.0164)*
L(Θ)	3871		4734		7499		2864
LB(12)	10.12[0.61]		14.20[0.29]		11.45[0.49]		9.88[0.61]
$LB^2(12)$	7.56[0.82]		2.56[0.99]		12.49[0.41]		5.34[0.95]

Figures in parentheses denote standard errors, while figures in brackets denote p-values. L(Θ) is the value function and LB is the Ljung-Box statistic for serial correlation.

* denotes significance at the 1% level.

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