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VOLATILITY SPILLOVER EFFECTS IN THE EXTRA VIRGIN OLIVE OIL MARKETS OF THE MEDITERRANEAN

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Abstract

The objective of this study is to assess the existence and magnitude of volatility spillovers between the extra virgin olive oil markets of Italy, Spain and Greece. These three Mediterranean countries are responsible for 95% of olive oil production within the European Union and they account for more than 50% of olive oil exports worldwide. In order to measure the degree of volatility transmission between these countries we estimate a vector error correction model along with the BEKK parameterization of a Multivariate Generalized Conditional Autoregressive Heteroskedasticity (M-GARCH) model. The empirical results reveal the presence of ARCH and GARCH effects suggesting this way the existence of volatility spillovers between the extra virgin olive oil markets of Italy, Greece and Spain. ARCH effects are the biggest in magnitude for the market between Spain and Italy. GARCH effects are the biggest in magnitude for the market between Greece and Italy.

Keywords: *Olive oil, Mediterranean, Spillovers, GARCH – BEKK.*

1. Introduction

There is emerging consensus that the international agri-food system is becoming more vulnerable to extreme events of price volatility. The unprecedented price surge in agricultural commodities during the late 2007 and early 2008 food crisis has renewed the interest in analyzing the interactions of food markets. As agricultural markets around the world are increasingly integrated, food price shocks can transpire to domestic markets much quicker and with higher intensity than before. There is overwhelming evidence that volatility for many of the major internationally traded food commodities has been increasing over the past decade (Rapsomanikis & Mugera, 2011). Can such episodes of extreme price volatility in the international arena pose a serious threat to world food security? Does food market globalization come at a cost?

Market globalization, and more specifically food market integration, has been a subject of great importance for economists as well as for policy makers. The analysis of spatial price relationships helps economists to assess whether geo-graphically separated markets are segmented or integrated. The European Union (EU) has been engaged in a process of market integration for a long period of time (European Commission, 2012a). The adoption of the Single Market Programme by the EU resulted in the removal of all barriers between national markets. The main idea behind the Single Market Programme was to promote trade, create a more efficient market, and to increase the resilience to economic shocks. However, market efficiency begins to break down when price movements are increasingly uncertain and persist for an extended period of time.

Volatility, in economic theory, means variability and uncertainty. Uncertainty is inherent in agricultural production because of its nature. Unpredictable extreme weather events (droughts) as well as natural disasters (floods) can influence a great deal production and hence agricultural prices. At the same time, agricultural commodities form the basis for family income, especially in developing countries.

Events of extreme price volatility have negative implications for the economic welfare of many households in these countries and constitute a major threat to food security (Rapsomanikis, 2011). Moreover, their impact falls heavier on the poor who spend as much as 70% of their income on food.

Greece, Italy, and Spain were among the countries that were affected the most by the recent economic crisis. Greece stopped having access to financial markets since 2010.[1] Spain and Italy had to take drastic austerity measures to overcome the hardship. The budgetary constraints that the recent economic crisis imposed on these three countries have made it much harder for the governments to intervene and provide financial support to the producers of agricultural commodities when extreme events of price volatility occur. A better understanding of volatility spillovers between global agri-food markets can assist in policy formulation. Despite the importance of this issue, the number of studies on the transmission of price volatility and on price interrelationships for spatial EU agri-food markets has been rather small.

Against this background, the objective of this study is to analyze volatility spillovers between the extra virgin olive oil markets of Italy, Spain, and Greece. These three countries of the Mediterranean are responsible for 95% of olive oil production within the EU. 73% of the world olive oil production comes from the EU. On the other hand, Italy, Spain and Greece account for 80% of olive oil consumption within the EU (European Commission, 2013a). Statistics regarding olive oil trade among these three countries are quite remarkable. 72% of Spain’s exports and 88% of Greek exports have Italy as their destination; 98% of Italy’s imports from EU members come from Spain and Greece. The exports of Spain and Greece to Italy consist to a large degree of extra virgin and virgin olive oil (European Commission, 2012b). For the year 2014, extended droughts in Spain and unfavorable weather conditions in Italy were expected to reduce olive oil production by 35% and 50% respectively. A price surge, especially in the price of the extra virgin olive oil was to be expected.

To the best of our knowledge, there are no publicly available econometric studies that address volatility spillovers between the extra virgin olive oil markets of Spain, Italy, and Greece. Volatility spillovers reflect the co-movement of price variances in these markets. We follow a multivariate Generalized Autoregressive Heteroskedasticity (GARCH) approach that allows us to evaluate volatility transmission. Multivariate models are valuable tools for researchers and decision makers when volatilities move together over time across markets. Although we find many applications of vector autoregression and GARCH models in the finance literature (Lee & Stewart, 2010), such analyses in agricultural economics is not so common. In agricultural economics extensive work has focused on price transmission (Buguk et al., 2003), less has considered implications of price volatility. In one of them, Rapsomanikis & Mugera (2011) used a Bivariate Vector Error Correction model to assess price transmission from selected international food markets to developing countries. Furthermore, they introduced a Generalized Conditional Autoregressive Heteroskadisticity effect for the model’s innovations, in order to assess volatility spillover between the world and the markets of Ethiopia, India, and Malawi. Their results indicate that volatility spillovers are significant during periods of extreme world market volatility.

Regarding the olive oil market, Emmanoulides, Fousekis, and Grigoriadis (2013) utilized the statistical tool of copulas to assess the degree and the structure of price dependence in the principal EU olive oil markets (Spain, Italy, and Greece) for the case of extra virgin and lampante olive oil. According to their results prices are likely to boom together but not to crash together. This is true especially for the prices of the two most important players, Italy and Spain. Additionally, their finding of asymmetric price co-movements implies that the three principal spatial olive oil markets in the European Union cannot be thought of as one great pool.

This study is organized as follows. Section 2 discusses the modeling framework. Section 3 describes the data. Section 4 presents the empirical models and the results. Conclusions and policy implications are presented in the last section.

2. Theoretical Model

If two prices from two spatially separated markets are co-integrated, the vector error correction model can be represented as:

$$\Delta P_t = \mu + \Pi P_{t-1} + \sum_{j=1}^{k} \Gamma_i \ \Delta P_{t-j} + e_t \qquad (1)$$

where $e_t \sim N(0, H_t)$ are normally distributed disturbances with zero mean and a variance-covariance matrix denoted by H_t. The Δ operator denotes that the variables have been differenced once in order to achieve stationarity.

More analytically, the VEC model is represented as:

$$\Delta P_{1,t} = \mu_1 + \pi_1\left(P_{1,t-1} - \beta P_{2,t-1}\right) + \sum_{j=1}^{k} \Gamma_i \ \Delta P_{t-j} + e_{1,t} \qquad (2)$$

$$\Delta P_{2,t} = \mu_2 + \pi_2\left(P_{1,t-1} - \beta P_{2,t-1}\right) + \sum_{j=1}^{k} \Gamma_i \ \Delta P_{t-j} + e_{2,t} \qquad (3)$$

Equations (2) and (3) are solved simultaneously in order to estimate the degree of price transmission between the two markets. The markets under consideration in our study are represented by the countries of Italy (IT), Greece (GR), and Spain (ES). Accordingly, $P_{1,t}$ represents the price of extra virgin olive oil in one of the above mentioned countries, and $P_{2,t}$ represents the price of extra virgin olive oil in the other of the three countries. On the right hand side, the term in parenthesis represents the stationary long-run equilibrium relation between the two variables. The coefficients π_1 and π_2 measure the degree to which price series adjust to the long-term equilibrium relationship (term in parenthesis) in equations (2) and (3) respectively.

The vector error correction model representation provides us with the conditional expected means of the variables and reveals to us how the predictable portions of price changes in one market transmit to the other market and vice versa.

In order to capture volatility spillovers we specify the VEC model's errors as a multivariate GARCH procedure. The estimation of equations (2) and (3) generates residuals that are then used to estimate the BEKK conditional variance-covariance matrix. The BEKK (named after BABA, ENGLE, KRAFT and KRONER) parameterization assumes a quadratic form for the parameter matrices in such a way so that the covariance matrix is positive semi-definite (Engle, 1982; Bollerslev, 1986; Engle & Granger, 1987; Engle & Kroner, 1995). This is a necessary condition in order for the estimated variances to be non-negative.

The BEKK parameterization is expressed as follows:

$$H_t = C'C + \sum_{j=1}^{q} A' e_{t-j} e'_{t-j} A \ + \sum_{j=1}^{q} G' H_{t-j} G \qquad (4)$$

where H_t is the kxk conditional variance matrix, C is an upper triangular matrix of dimensions k, and A and B are kxk matrices without restrictions. A is the matrix of ARCH parameters, and B is the matrix of GARCH parameters. Equation (4) produces positive definite matrices H_t for all possible e_t as long as C or B are of full rank. For a closer look, we consider a bivariate GARCH (1,1) model with j=1, as follows:

$$H_t = \begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{12,t} & h_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} \\ c_{12} & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{12} & a_{22} \end{bmatrix} \begin{bmatrix} e^2_{1,t-1} & e_{1,t-1}e_{2,t-1} \\ e_{1,t-1}e_{2,t-1} & e^2_{2,t-1} \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{12} & a_{22} \end{bmatrix} + \begin{bmatrix} g_{11} & g_{12} \\ g_{12} & g_{22} \end{bmatrix} H_{t-1} \begin{bmatrix} g_{11} & g_{12} \\ g_{12} & g_{22} \end{bmatrix} \quad (5)$$

$$h_{11,t} = c_{11} + a_{11}e^2_{1,t-1} + 2a_{11}a_{21}e_{1,t-1}e_{2,t-1} + a^2_{21}e^2_{2,t-1} + g^2_{11}h_{11,t-1} + 2g_{11}g_{21}h_{12,t-1} + g^2_{21}h_{22,t-1} \quad (6)$$

$$h_{12,t} = c_{12} + a_{11}a_{12}e^2_{1,t-1} + (a_{12}a_{11} + a_{11}a_{22})e_{1,t-1}e_{2,t-1} + a_{21}a_{22}e^2_{2,t-1} + g_{11}g_{12}h_{11,t-1} + (g_{21}g_{12} + g_{11}g_{22})h_{12,t-1} + g_{21}g_{22}h_{22,t-1} \quad (7)$$

$$h_{22,t} = c_{22} + a_{12}e^2_{1,t-1} + 2a_{12}a_{22}e_{1,t-1}e_{2,t-1} + a^2_{22}e^2_{2,t-1} + g^2_{12}h_{11,t-1} + 2g_{12}g_{22}h_{12,t-1} + g^2_{22}h_{22,t-1} \quad (8)$$

where $a_{21} = a_{12}$, $g_{21} = g_{12}$ and H_t is positive definite by construction.

As we can see from equations (6), (7), and (8), the conditional variances and co-variances are a function of the model's error terms and the lagged variances. Matrix A captures the ARCH effects and matrix G measures the GARCH effects. More specifically, the parameters in matrix A measure the impact of past shocks on volatility, while parameters in matrix G capture the effects of past volatility on the current conditional variance. On the whole, statistically significant parameters indicate the presence of ARCH and GARCH effects. The element $h_{12,t}$ which is given by equation (7) accounts for the co-variance between the two variables, capturing this way volatility spillovers between the two markets under consideration. Thus, the BEKK model enables us to model temporal interactions between shocks in different markets by estimating the conditional co-variance, $h_{12,t}$. This allows not only the assessment of the impact of shocks on the co-variance, but also the impact of time varying correlations between the shocks in different markets and the degree to which volatility spills over. Although the BEKK model ensures the positive definiteness of H_t, the number of parameters to be estimated is quite large. Due to this fact, estimation of this model is often infeasible (non-convergence). To reduce the number of parameters it is common to assume that the coefficients matrices A and G are diagonal. This restricted version of the BEKK model is the diagonal BEKK which is expressed as:

$$H_t = \begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{12,t} & h_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11} & 0 \\ 0 & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & 0 \\ 0 & a_{22} \end{bmatrix} \begin{bmatrix} e^2_{1,t-1} & e_{1,t-1}e_{2,t-1} \\ e_{1,t-1}e_{2,t-1} & e^2_{2,t-1} \end{bmatrix} \begin{bmatrix} a_{11} & 0 \\ 0 & a_{22} \end{bmatrix} + \begin{bmatrix} g_{11} & 0 \\ 0 & g_{22} \end{bmatrix} H_{t-1} \begin{bmatrix} g_{11} & 0 \\ 0 & g_{22} \end{bmatrix} \quad (9)$$

$$h_{11,t} = c_{11} + a^2_{11}e^2_{1,t-1} + g^2_{11}h_{11,t-1} \quad (10)$$

$$h_{12,t} = a_{11}a_{22}e_{1,t-1}e_{2,t-1} + g_{11}g_{22}h_{12,t-1} \quad (11)$$

$$h_{22,t} = c_{22} + a^2_{22}e^2_{2,t-1} + g^2_{22}h_{22,t-1} \quad (12)$$

where volatility spillovers between the two markets are captured by the term $h_{12,t}$ which is given by equation (11).

3. The data

For the empirical analysis we use monthly extra virgin olive oil prices (measured in euros per 100 kilograms) from Italy, Spain, and Greece. The time period of interest is January 2000 to May 2014. Data were obtained from the European Commission (2014). Figure 1 presents the prices of the extra virgin olive oil for Italy, Spain, and Greece.

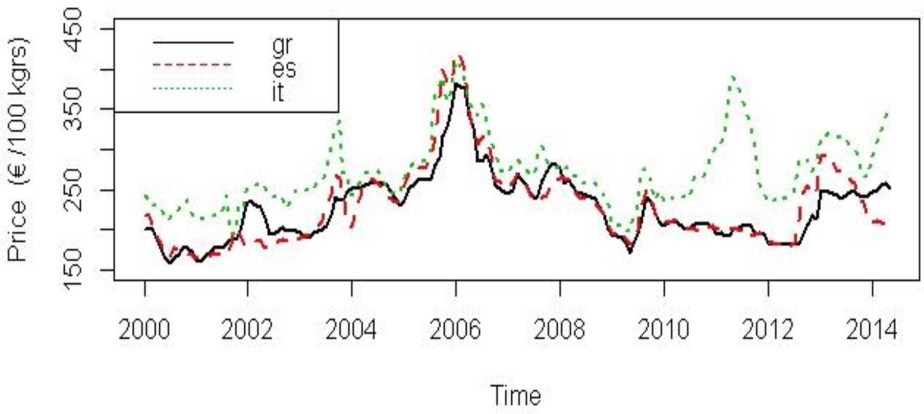

Figure 1. Extra Virgin Olive Oil Prices (Euros per 100 kilograms)

Prices in Greece and Spain have been moving quite similar to each other throughout the period considered in this article. Italian extra virgin olive oil prices are higher compared to prices from Greece and Spain. Overall, prices move very close together, apart for the time period (approximately) 2010-2011.[2]

Table 1 provides the descriptive statistics of the variables included in our model. The mean of the extra virgin olive oil price is higher in Italy than it is in the other two markets. In Spain and Greece the mean price is almost identical.

Table 1. Summary Statistics for the Prices of Extra Virgin Olive Oil

Extra Virgin Olive Oil Price	Observations	Mean	St. Dev.	Min	Max
P_{IT}	173	272.95	46.50	195	412.5
P_{ES}	173	229.5	51.8	162.1	421
P_{GR}	173	226.7	42.45	158.8	382.1

Note: Prices are in Euros per 100 kilograms

According to the relevant Regulation by the European Commission, the extra virgin category refers to olive oils obtained from the fruit of the olive tree at the optimum stage of ripening, solely by mechanical or other physical means that do not lead to alteration of the oil and have not undergone any treatment other than washing, decantation, centrifugation or filtration. Extra virgin olive oil has a maximum of 0.8 grams oleic acid per 100 grams of oil3.

In numbers, Spain with 60%, Italy with 21% and Greece with 14% account for about 95% of the EU production. Worldwide, Spain is the leading olive oil producer; 35% of the total olive oil production in Spain is extra virgin. Italy comes in second place worldwide; 60% of the production in Italy is extra virgin olive oil (European Commission, 2013b). Greece holds third place; it produces approximately 350,000 tons of olive oil annually, of which more than 80% is extra virgin. With regard to consumption patterns, Italy and Greece consume primarily extra virgin olive oil, whereas consumption of extra virgin olive oil in Spain represents less than 50% of the total olive oil domestic consumption (European Commission, 2012b). European Union is the world's biggest consumer of olive oil, with a share of 66%. Spain, Italy, and Greece account for about 80% of the EU's consumption (Emmanoulides, Fousekis, & Grigoriadis, 2013).

Statistics regarding trade among these three Mediterranean countries are quite interesting. 72% of Spain's exports and 88% of Greek exports have Italy as their destination; 98% of Italy's imports from EU members come from Spain and Greece.

The exports of Spain and Greece to Italy consist to a large degree of extra virgin and virgin olive oil, sold in bulk; these are subsequently bottled and/or blended by a small number of major Italian companies and are distributed worldwide (Emmanoulides, Fousekis, & Grigoriadis, 2013). Especially for the case of Greece, nearly half of the annual olive oil production is exported but only some 5% of this reflects the origin of the bottled product. Trade flows between Spain and Greece are insignificant when compared with those of the two countries with Italy. It is worth mentioning that although Italy is a deficit market within the EU, it is one of the biggest olive oil exporters in the world, with a share of about 30%. In 2012-2013 Italy accounted for the 48.6 % of the total of US olive oil imports. Spain's share worldwide is 18% (Emmanoulides, Fousekis, & Grigoriadis, 2013).

4. Empirical Models and Results

We formulate three different pairs of the price series considered in our study. The pairs are: Italy-Greece, Italy-Spain and Greece-Spain. For each pair we are going to investigate empirically the existence and the magnitude of volatility spillover effects between the two markets. The order of integration of the price series is assessed by the Augmented Dickey Fuller (ADF) test (Dickey & Fuller, 1979). All series were found to be non-stationary and integrated of order one. Results are presented in Table 2.

Table 2. Augmented Dickey Fuller Test for Non–stationarity

Extra Virgin Olive Oil Price	Levels	First Difference
P_{IT}	-2.89	-9.98
P_{ES}	-2.19	-8.35
P_{GR}	-2.17	-8.61

Note: The 1% critical value for both tests is -3.47. The appropriate lag length was chosen on the basis of the Schwartz-Bayes criterion.

Table 3 presents the results of the Johansen test for co-integration between the three pairs of extra virgin olive oil prices of Italy, Spain and Greece (Johansen, 1988, 1991, 1995). The test strongly rejects the null hypothesis of no co-integration, suggesting the existence of a long-run equilibrium between the prices for each of the three pairs during the time period used in this study.

Table 3. Test statistics for Johansen Test

	Number of cointegrating vectors	
Extra Virgin Olive Oil Prices	r = 0	r = 1
P_{Italy}-P_{Spain}	15.55	5.22
P_{Italy}-P_{Greece}	16.28	5.56
P_{Greece}-P_{Spain}	15.60	5.27
P_{Italy}-P_{Greece}-P_{Spain}	29.91	14.48

Note: In all three pairs the case of no co-integrating vector is rejected at the 5% level of significance (critical value is 15.49). For all three pairs, the trace test indicates the existence of co-integrating equation(s) at the 5% level of significance. For the case of co-integration between all three variables, the case of no co-integrating vector is rejected at the 5% level (critical value is 29.79), while the case of one co-integrating vector cannot be rejected at the 5% level (critical value is 15.49).

For the empirical implementation of the VEC and the GARCH–BEKK models we use logarithmic transformations of the price series. We estimate three VEC models (one for each pair). The estimated parameters are presented in Table 4. The term u_t accounts for the errors from the long-run equilibrium relationship for each of the three pairs.

Table 4. Estimated Parameters of the Vector Error Correction Models

coefficient	Italy – (*i*)	Greece (*j*)	Italy – (*i*)	Spain (*j*)	Greece – (*i*)	Spain (*j*)
	ΔP_{ITt}	ΔP_{GRt}	ΔP_{ITt}	ΔP_{ESt}	ΔP_{GRt}	ΔP_{ESt}
u_t	-0.108** (0.047)	0.013 (0.028)	-0.094*** (0.032)	-0.015 (0.025)	-0.155*** (0.035)	-0.037 (0.036)
ΔPi_{t-1}	0.264** (0.108)	0.169*** (0.043)	0.019 (0.115)	0.079* (0.034)	0.432*** (0.080)	0.106 (0.086)
ΔPi_{t-2}	-0.009 (0.092)	-0.018 (0.051)	0.120 (0.102)	0.099 (0.072)	0.056 (0.102)	0.225*** (0.081)
ΔPj_{t-1}	0.086 (0.138)	0.372*** (0.119)	0.239*** (0.092)	0.537*** (0.109)	0.094** (0.044)	0.395*** (0.115)
ΔPj_{t-2}	-0.032 (0.134)	0.016 (0.097)	-0.158 (0.110)	-0.190* (0.102)	0.006 (0.069)	-0.150 (0.106)

Notes: 1) The appropriate lag length was chosen on the basis of the Schwartz-Bayes criterion. **2)** (***), (**), and (*): significance at 1%, 5%, and 10% level respectively.

For the pair of Italy with Greece, the estimated parameter of the adjustment process of the Italian extra virgin olive oil price to the Greek price is statistically significant. On average, 10.8% of the divergence in the price in Italy from its long-run equilibrium is corrected each month. The estimated parameter of the adjustment process of the Greek extra virgin olive oil price to the Italian price is not statistically significant. The non-significant error correction coefficient in the Greek price equation of the VEC model suggests that the price of the Greek extra virgin olive oil is weakly exogenous for the pair of Italy with Greece.

For the pair of Italy with Spain, the VECM suggests that the estimated parameter of the adjustment process of the Italian extra virgin olive oil price to the Spanish price takes the value of -0.094, and is significant at the 1% level of significance. This means, on average, 9.4% of the divergence in the price in Italy from its long-run equilibrium, is corrected each month. The estimated parameter of the adjustment process of the Spanish extra virgin olive oil price to the Italian price is not statistically significant. The non-significant error correction coefficient in the Spanish price equation of the VEC model suggests that the price of the Spanish extra virgin olive oil is weakly exogenous for the market between Italy and Spain.

As we can observe, the Greek extra virgin olive oil price and the Spanish extra virgin olive oil price are weakly exogenous for the pairs of Italy–Greece and Italy–Spain respectively. One possible explanation about the direction of the adjustment process in both pairs can be the fact that Italy depends significantly on imports of extra virgin olive oil from Greece and Spain: 98% of Italy's imports from EU members come from Spain and Greece and the majority of them consist of extra virgin olive oil.

For the pair of Greece with Spain, the estimated parameter of the adjustment process of the Greek extra virgin olive oil price to the Spanish price is statistically significant. On average, 15.5% of the divergence in the price in Greece from its long-run equilibrium is corrected each month. The estimated parameter of the adjustment process of the Spanish extra virgin olive oil price to the Greek price is not statistically significant. The non-significant error correction coefficient in the Spanish price equation of the VEC model suggests that the price of the Spanish extra virgin olive oil is weakly exogenous for the market between Greece and Spain. Thus, the Spanish extra virgin olive oil price is weakly exogenous in all cases considered in this work. This can be attributed to the fact that the country of Spain is the most important olive oil producer worldwide, accounting for almost 45% of the world olive oil production.

In the last step, we estimate the BEKK parameterization of the three bivariate GARCH models formed in our study. In order to get convergence we estimate a diagonal BEKK model. The estimated parameters are in Table 5.

ARCH effects, as measured by the parameters a_{11} and a_{22} for every pair, are the biggest in magnitude for the pair Italy–Spain. The estimated value for a_{11} is 0.807 and for a_{22} is 0.719. Both are statistically significant at the 1% level. These ARCH estimates indicate that the impact of past shocks on the current conditional variance–covariance is the highest for the market between Spain and Italy.

GARCH effects, as captured by the parameters g_{11} and g_{22} for every pair, are the biggest in magnitude for the pair Italy–Greece. The estimated values for g_{11} is 0.759 and for g_{22} is 0.637, and are significant at the 5% and 1% level of significance respectively. These estimates of the GARCH parameters indicate the impact of past volatility on the current conditional variance–covariance is the highest for the market between Greece and Italy. Overall, in all three pairs, we have evidence of volatility spillover effects due to the existence of statistically significant ARCH and GARCH parameters, making this way the term $h_{12,t}$ that measures spillovers in volatility (eq.11) statistically significant as well. As the results reveal, we have the strongest ARCH and GARCH effects for the pairs of Italy–Spain and Italy–Greece respectively.

The significance and the magnitude of the ARCH and GARCH effects for the pairs of Italy–Spain and Italy–Greece provide us with another piece of evidence about the big dependence of the olive oil bottling industry in Italy for imports from Greece and Spain.

Table 5. Estimated GARCH-BEKK Parameters

coefficient	Italy - Greece		Italy - Spain		Greece - Spain	
	i=1	i=2	i=1	i=2	i=1	i=2
$\mathbf{a_{1i}}$	0.215* (0.120)		0.807*** (0.096)		0.602** (0.120)	
$\mathbf{a_{2i}}$		0.647*** (0.150)		0.719*** (0.114)		0.810*** (0.108)
$\mathbf{g_{1i}}$	0.759** (0.345)		0.486*** (0.121)		0.678*** (0.145)	
$\mathbf{g_{2i}}$		0.637*** (0.137)		0.648*** (0.087)		0.647*** (0.075)

Notes: 1) We do not include the parameters of the matrix C since they do not alter the quality of our results. **2)** (***), (**), and (*): significance at 1%, 5%, and 10% level respectively.

Italy, as the biggest olive oil exporter in the world, in order to maintain its strong position has to keep offering extra virgin olive oil with a specific taste profile. Olive oil quality characteristics such as taste, aroma, and texture depend to a very large degree on the country of origin of production (Vossen, 2007).

As Emmanoulides, Fousekis and Grigoriadis (2013) mention the imports of bulk extra virgin olive oil from Greece and Spain are bottled and/or blended by a small number of major Italian companies and are sold at the international markets. Thus, the olive oil bottling and blending industry in Italy depends to a large degree on imports of extra virgin olive oil from Spain and Greece because of its taste profile, which subsequently is used as a tool of product differentiation and market segmentation. This is especially the case for the pair Italy–Greece: 88% of Greek exports of olive oil have Italy as their destination, when at the same time 82% of the Greek olive oil production is extra virgin. One can assume that Greek exports are quite important for the olive oil bottling / blending industry of Italy in its effort to differentiate and market its product. The values of the estimated GARCH parameters for the pair Italy–Greece support our theory. Volatility spillovers are the greatest in magnitude for the extra virgin olive oil market formed between Italy and Greece.

5. Conclusions and Policy Implications

Volatility spillovers in spatial agri-food markets is an economic phenomenon that has gained importance in recent years. There is emerging consensus that the international agri-food system is becoming more vulnerable and susceptible to extreme events of price volatility. As agricultural markets around the world are increasingly integrated, food price shocks can transpire to domestic markets much quicker and with higher intensity than before. The sudden and unpredictable increases in many internationally traded food commodity prices in late 2007 and early 2008 strengthened the attention to the global food system and fueled the debate about the reliability of world markets as a secure source of food. Are events of extreme price volatility in the international arena a serious threat to world food security?

From the EU's perspective, institutional reasons for addressing volatility lie within the original Common Agricultural Policy (CAP) objectives of stabilizing agricultural markets and ensuring a fair standard of living for farmers. Price interdependence and co-movement of price variances have considerable interest for policy makers, since transition of price shocks across geographically separated markets is a necessary condition for market efficiency. The European Union has pursued the goal of the integration of national markets over the last thirty years through a number of policies. Such policies aim to enhance integration, promote competition as well as benefit consumers through more choices and lower prices. On the other hand, such measures will increase the spillover effects during episodes of high volatility in some of these markets. Extreme price volatility comes at a cost. Large unexpected price upswings are a big threat to food security. Their impact falls heaviest on the farmers. Farmers are highly dependent on commodities for their living.

Extreme volatility can result in large income fluctuations, for which most of the times they have little or no resources to insulate themselves from extreme situations like this. To add insult to injury, the lag between production decisions and actual production introduces more risks, as farmers base their planning and investment on expected future prices.

Greece, Italy and Spain were among the countries that were affected by the recent economic crisis the most. At the same time, for the year 2014, unfavorable weather conditions in Spain and Italy were expected to reduce olive oil production and increase the price of extra virgin olive oil. In previous episodes of extreme price volatility, governments could intervene at least at the micro level, with targeted subsidies and provide a safety net for farmers. The budgetary constraints that the recent economic crisis imposed on these three countries have made it much harder for the governments to intervene and provide financial support to the producers of agricultural commodities. In the long run, Italy, Greece and Spain can lower their vulnerability by raising their productivity for a variety of agricultural products. In the short run however, there are fewer options to deal with price uncertainty.

Olive oil trade among Italy, Greece and Spain is very significant. 72% of Spain's exports and 88% of Greek exports have Italy as their destination; 98% of Italy's imports from EU members come from Spain and Greece. In this context, the objective of this study has been to investigate volatility spillovers between the extra virgin olive oil markets of these Mediterranean countries. This objective has been pursued by utilizing a VECM along with a multivariate GARCH– BEKK model.

According to the empirical results, there is evidence of volatility spillovers between the extra virgin olive oil markets of Italy, Spain and Greece. The market between Spain and Italy exhibits the strongest ARCH effects. The market between Greece and Italy has the strongest GARCH effects. This is another indicator of the big dependence of the Italian olive oil bottling industry on extra virgin olive oil imports from Greece and Spain.

The present study utilizes a multivariate GARCH model, in order to examine volatility spillovers between the three biggest players in the extra virgin olive oil market within the European Union. Countries like Portugal, Turkey, New Zealand, The Republic of South Africa, Argentina and Chile also produce a considerable amount of extra virgin olive oil. Future research can consider and examine if there are volatility spillovers between important players in the extra virgin olive oil market amongst the rest of the world.

References

Bollerslev, T. (1986). Generalized Autoregressive Conditional Heteroskedasticity. *Journal of Econometrics* 31(3):307–327.

Buguk, C., Hudson, D., & Hanson, T. (2003). Price Volatility Spillover in Agricultural Markets: an Examination of US Catfish Markets. *Journal of Agricultural and Resource*

Economics, 86–99.
Dickey, D. & Fuller, W. (1979). Distribution of the Estimators for Autoregressive Time Series with a Unit Root. *Journal of American Statistical Association*, 74:427– 431.
Emmanoulides, C. Fousekis, P., & Grigoriadis, V. (2013). Price Dependence in the Principal EU Olive Oil Markets. *Spanish Journal of Agricultural Research, 1*2(1):3–14.
Engle, R. F. (1982). Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation. *Econometrica: Journal of the Econometric Society,* 987–1007.
Engle, R. F. & Granger, C. W. (1987). Co-integration and Error Correction: Representation, Estimation, and Testing. *Econometrica: Journal of the Econometric Society,* 251–276.
Engle, R. F. & Kroner, K. F. (1995). Multivariate Simultaneous Generalized Arch. *Econometric theory,* 11(01):122–150.
European Commission (2012a). Economic and Financial Affairs – Market Integration and Internal Market Issues.
European Commission (2012b). Statistics for Olive Oil. DG for Agriculture and Rural Development, Brussels.
European Commission (2013a). Olive Oil. Agriculture and Rural Development, Brussels.
European Commission (2013b). Olive Oil Statistics. Advisory Committee, Lucie ZOLICHOVÁ, DG AGRI C.2.
European Commission (2014). Olive Oil Prices and Trade Data. DG for Agriculture and Rural Development, Brussels.
Johansen, S. (1988). Statistical analysis of Co-integration Vectors. *Journal of Economic Dynamics and Control,* 12(2):231–254.
Johansen, S. (1991). Estimation and Hypothesis Testing of Co-integration Vectors in Gaussian Vector Autoregressive Models. *Econometrica: Journal of the Econometric Society,* 1551–1580.
Johansen, S. (1995). Likelihood-based Inference in Co-integrated Vector Autoregressive models. *OUP Catalogue.*
Lee, J. & Stewart, G. (2010). Asymmetric Volatility and Volatility Spillovers in Baltic Nordic Stock Markets. *European Journal of Economics, Finance and Administrative Sciences,* 25 136–143.
Rapsomanikis, G. (2011). Price Transmission and Volatility Spillovers in Food markets. Food and Agriculture Organization of the United Nations, Rome, 2011. Safe-guarding Food Security in Volatile Global Markers, 165–179.
Rapsomanikis, G. & Mugera, H. (2011). Price Transmission and Volatility Spillovers in Food Markets of Developing Countries. Methods to Analyze Agricultural Commodity Price Volatility, 165–179.
Vossen, P. (2007). Olive oil: History, Production, and Characteristics of the World's Classic Oils. *HortScience,* 42(5):1093–1100.

Footnotes

[1]Greece regained access to financial markets, for a short period of time, in April of 2014.

[2]The hike in price in the Italian market has been attributed to an increase in production costs (Advisory Group on Olives and Derived Products - Report of the Meeting in June 2011).

[3]Other categories of olive oil: virgin olive oil with 0.8 to 2 grams of oleic acid per 100 grams, lampante oil with 2 to 5 grams of oleic acid per 100 grams, olive-pomance oil, and refined olive oil.