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Article

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International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2020, 10(3), 423-428.

Analysis of Olive Oil Market Volatility Using the ARCH and GARCH Techniques

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Received: 23 December 2019 **Accepted:** 25 February 2020 **DOI:** https://doi.org/10.32479/ijeep.9138

ABSTRACT

Agricultural prices variation analysis is essential for the formulation of public policies and business decisions. Considering the strategic importance of olive oil for producers and consumers alike, as well as its potential economic and social benefits, this study aims to quantify the volatility of olive oil prices. The models are estimated using monthly data of olive oil prices (from January 1980 to February 2017) that was collected from IMF statistics. ARCH and GARCH models were used to estimate price volatility. Our results for olive oil show that volatility clashes of prices does not last for a long period of time, and thus olive oil is an interesting culture for new producer markets, as it is not a product that suffers from a huge volatility in price in the international market, mitigating the risk to rural producers and encouraging new local businesses. This study is limited by the data analysed and the methodology used. Further research should include more data and other statistical approaches (e.g., econometric panel data that considers different countries and several explanatory variables for price volatility).

Keywords: Olive Oil, Volatility, ARCH, GARCH
JEL Classifications: Q02, Q42, O13

1. INTRODUCTION

Apart from having an economic importance for producers and being a food item for consumers, olive oil production is tied to the roots of civilization. According to Luchetti (2002), olive oil cultivation goes back 6000 years. Its history starts in the Mediterranean shores of Palestine and Syria, from where its production expanded to Turkey, via Cyprus and then on to Egypt via Crete. It should be said, however, that its importance is not merely historical, but rather current, as it is one of the most consumed foods in the world.

Despite being produced and marketed worldwide by countries located in the Mediterranean region, the planting of olives has been shown to be promising in other regions of the world. About 70% of olive oil production is from the Mediterranean, mainly from the European Union countries of Spain (the leader, with almost 43% of production), Italy, Greece, and Portugal, followed by the southern Mediterranean Countries of Syria, Tunisia, Turkey, Morocco, and Algeria, which account for 24% of production (Munõz et al., 2015). The increasing importance of "non-traditional" olive oil producers, such as Argentina, Australia, or South Africa, is due to the growth of olive oil world consumption, due to it being a key element of the Mediterranean diet and its health benefits (Gázquez-Abad and Sánches-Pérez, 2009). Accordingly, several countries are working to adapt olive trees to other climates and soils, a key example being Brazil, which is at an initial stage of investment in olive oil production. Other Latin American Countries, such as Chile, Argentina, and Uruguay, already have a developed olive oil industry and have even begun to export olive oil (Torres and Maestri, 2006; García-González et al., 2010; Gámbaro et al., 2011; Romero and Aparicio, 2010; Wrege et al., 2015).

Thus, olive oil production is an issue that is currently widely discussed in the literature, as it is a commodity that can contribute positively to the wealth of a given country, by generating employment and income opportunities, as well as providing health benefits through its consumption. In this way, studies that analyse the behaviour of olive oil production and units of consumption in terms of price variation, as its production can affect producers and/or consumers alike (Krystallis and Chryssohoidis, 2005; Tsakiridou et al., 2006; Vlontzos and Duquenne, 2014; Bajoub et al., 2016).

On the other hand, olive oil represents a singular market. Some consumers have preference for labels of geographical origin, and thus price variations can severely affect markets around the world (Menapace et al., 2011). A growing body of literature has pointed out other singularities of this market, such as farm production dependence, harvested acreage, weather, soil conditions, climate crisis, value-adding activities, production sustainability, organic and place of origin attributes, adjustment between supply and demand, government incentives, exchange rate, gross domestic product, etc., (Kohls and Uhl, 1990; Siskos et al., 2001; Menozzi, 2014).

According to this assembled opinion, there is a variety of areas and relevant research topics regarding the olive oil market. As example, Scarpa and Del Giudice (2004) presented a study aiming to analyse and contrast urban Italian consumers' preferences regarding extra-virgin olive oil. To understand such preferences, it is quite important, however, it is essential to understand the customers' perspectives regarding olive oil consumption, as was carried out by Sandalidou et al. (2002). The microeconomic principle of consumers' willingness to pay for it is also exploited, as Kalogeras et al. (2009) found out. Romo et al. (2015), in turn, compare olive oil with wine, as it presents various similar intrinsic and extrinsic attributes.

In this context, an analysis of olive oil price volatility is crucial. This is not merely due to the fact that olive oil is a food source with a high commercial value, but also because maladjustment in production levels can produce difference in prices. Cyclic and/or seasonal fluctuations can severely compromise farmers and their incomes, as well as disrupt urban population consumption levels. Therefore, understanding the volatility fluctuation pattern of these prices can help in the design of the policies that need to be implemented to stabilise product prices over the years.

This paper aims to analyse the volatility of olive oil returns during the period from 1980 to 2017. Specifically, it intends to: (a) Analyse the volatility of the conditional olive oil price; (b) identify the reaction and persistence of volatility mechanism against shocks, and; (c) identify possible risks for rural producers, providing insights into public policies for rural development. In the literature some studies exist that study the prices of agricultural commodities. As examples, one can refer to the study of Beck (2001), Ramirez and Fadiga (2003), Jacks et al. (2011), Emmanouilides et al. (2013), and Abid and Kaffel (2017). This study innovates and differs from these others, since it is based specifically on olive oil returns, according, and therefore, in order to understand the behaviour of returns, it deals with the parametric models of conditional autoregressive to measure olive oil price volatility, according to the ARCH and GARCH techniques.

This paper is organised as follows: after this introduction, which describes the main characteristics of the olive oil market and its current situation, a brief description of the methodology and data is provided in Section 2. Section 3 is devoted to presenting the results and their discussion. Finally, Section 4 provides the concluding remarks and some recommendations.

2. METHODOLOGY AND DATA

For managers, investors, regulators, and governments in general, it is very important to measure and forecast the volatility of prices, and one of the most robust empirical approaches is the Autoregressive Conditional Heteroscedasticy Model (ARCH), developed by Engle (1982), and generalised by Bollerslev (1986) in the GARCH model (Bollerslev et al., 1994; Engle and Patton, 2001; Greene, 2012). The importance of risk and uncertainty in several decision analysis issues in Economics and Finance (for example investments, pricing policy, portfolio selection, regional development policies, etc.) explains the academic and empirical development and visibility of ARCH and GARCH. There are several empirical applications of ARCH and GARCH models to volatility analysis. By carrying out a detailed analysis across the Web of Science database (WOS) related to the expression "Volatility ARCH," it is possible to prove the scientific relevance of this topic and the importance of this line of research, which has seen a significant increase over the years, with more than 1034 scientific papers published on the subject. It is noteworthy that 69% of the total studies are concentrated in the economics and administration fields.

According to the prices of extra-virgin olive oil, with 1% maximum acidity, this paper identifies the price behaviour pattern. For this, the paper intends to observe the presence of prediction errors on the prices, as well as verify heterocedastic patterns of their returns. The heterocedastic pattern may indicate instability and uncertainty in the financial market, due to changes in governments' economic policies and the currency exchange between countries (Engle, 1982; Engle and Bollerslev, 1986). The basic assumption is that the "ε_t" variance depends on "ε^2_{t-1}." The error term ε_t, conditioned to the period (t–1), is distributed as follows: $\varepsilon_t \sim \mathrm{N}[0, (\alpha_0 + \alpha_1.\varepsilon^2_{t-1})]$. This process can be generalised to "r" lags of ε^2, which is named ARCH (1). The conditional equation variance (1) defines an ARCH (r) model:

$$VAR(e_t) = \sigma_t^2 = \alpha_0 + \sum_{j=1}^{r} \alpha_j.\varepsilon^2_{t-j} \qquad (1)$$

Similarly, the GARCH model can be applied to olive oil, to describe volatility with fewer parameters than with ARCH. The GARCH model (1.1), shows that the errors variance of a model in period t will depend on three terms (Greene, 2012), namely: A medium term or constant; shocks of innovations on the volatility, which is determined by the square of the waste (ω^2_{t-1}) of the period t–1, represented by ARCH (outdated volatility information), and; the volatility revision made in the last period (σ^2_{t-1}), which is a

GARCH term (past predicted variances). The GARCH (1.1) model can be expressed by:

$$h_t = \omega = \alpha.\varepsilon_{t-1}^2 + \beta.\sigma_{t-1}^2 \quad (2)$$

To guarantee that the GARCH (1.1) is stationary, it is necessary that the sum of $\alpha_1 + \beta_1$ is <1. From these implications, it is possible to affirm that the volatility shocks persistence in olive oil returns series will be measured by this sum. If these coefficients sum low values (close to zero), this indicates that an initial shock on volatility will cause rapid effects on olive oil returns behaviour and that, after a short time period, the series variance should converge to its historical average. However, the larger (closer to one) the persistence coefficient value, the more slowly the shock on volatility dissipates (Greene, 2012).

The secondary data is adopted to measure the average monthly price of extra-virgin olive oil (with a maximum acidity of 1%). The series is derived from the UK Market, and was obtained from the International Monetary Fund (IMF, 2017), due to its reliability, and the main international trade route of the commodity under study is used. Prices were deflated in relation to US inflation, using the CPI-U series of the bureau labor service (BLS, 2017). The observations cover the period from January 1980 to February 2017 for oil olive oil prices (expressed in US $/t metric - ex-tanker), which comes to a total of 446 months.

3. RESULTS AND DISCUSSION

Olive oil consumption has been increasing worldwide, mainly due to its healthy nutritional properties (and also pharmaceuticals and cosmetics applications), and this fact could be seen as an opportunity for non-traditional producers, beyond Mediterranean shores. In fact, olive-producing areas are found between the 30° and 45° north and south latitudes (Luchetti, 2002), and as olive is a slow-growing tree, any policy for its development in rural areas should be based on a substantial economic analysis. The main producer countries accounted for about 95% of production, but there has been an increase in planting olive in non-Mediterranean countries, especially in South America (such as Argentina, Chile, and Brazil), South Africa and Australia. As microclimate has an important role in determining olive oil quality, taste and flavour (Azbar et al., 2004; Menozzi, 2014), there are opportunities for these countries.

Table 1: Descriptive statistics for olive oil returns

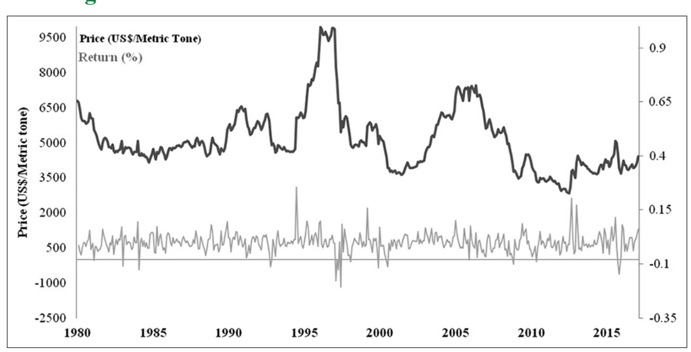
Statistics	Olive oil
Mean	−0.001
Standard deviation	0.045
Skewness	0.317
Kurtosis	8.127
Jarque-Bera	494.829

There are many socio-economic advantages associated with the cultivation of the olive tree, as it is an important source of revenue for farmers and a provider of employment for local rural workers, reducing the risk of land abandonment and contributing to landscape protection (Menozzi, 2014). In addition, olive trees are frequently grown in disfavoured regions. Combining these two factors, the olive tree could play a central role in any public policy for the development of poor/disfavoured regions and their sustainable development, boosting their long-term income (Lybbert and Elabed, 2013). As the consumption of olive oil in nontraditional markets (particularly North Europe, USA and Canada) has increased substantially (Kalogeras et al., 2009), potential new producers have the opportunity to play a role in the olive oil market. This is the final purpose of this paper: To analyse the volatility of olive oil prices, in order to come to conclusions about their potential utilisation for the development of low income rural areas.

During the period analysed from 1980 to 2017, the behavior of olive oil prices and return series varied according to the years (Figure 1), which also indicates some periods with low and high volatility for the series return, thus pointing to a dependence relation of this series in relation to its lagged periods. The results also indicate that the two main peaks observed in the series are in 1995-1996 and 2004-2006. The first of these was the result of several coincidental factors, including the mismatch between production and demand. According to the Planning and Policy Office, GPP (2007), the demand for olive oil between 1995 and 1996 was greater than the productive capacity of the sector, which, according to the law of supply and demand, increased the marketable prices of the product. However, according to the GPP (2007), this period was characterised by a significant increase in the consumption of olive oil per capita, which contributed to the increase in prices.

2004-2006 (the second period) represented a significant peak in the price of olive oil. The 2004/2005 harvest saw a drop of almost 30% in production, in comparison to the previous harvest. This fall

Figure 1: Prices and returns series for olive oil: 1980-2017



Source: IMF (2017)

Table 2: ADF test for the olive oil price

Commodity	ADF test–level		ADF test–first difference	
	Model I	Model II	Model I	Model II
Olive oil	−2.53 (−3.44)	−2.55 (−3.98)	−16.92 (−3.44)	−16.90 (−3.98)

ADF: Augmented Dickey-Fuller

was mainly due to an epidemic caused by the “Xylella” bacterium, known as the “Ebola of olive trees,” which decimated plantations in Italy, and also hit Spain, two of the world’s largest producers. However, the 2005/2006 crop managed to control the epidemic, although prices remained high, as there was no stockpiling of the product on account of the previous year’s crisis (Forbes, 2015).

Table 1 presents the descriptive statistics for commodity returns. The normality test estimation proposed by Jarque and Bera (1980) reveals the residuals non-normality. The asymmetry was positive and the kurtosis statistic, which measures the peak or flattening of the distribution, exceeds 3 (normal value), indicating a distribution with caudal flattening. The data are grouped in the centre, with some observations at the ends of the tails, and the returns follow a non-normal distribution (leptokurtic). Thus, the return series evidences the presence of heteroskedasticity.

After this initial descriptive analysis, it is possible to proceed a unit root test. Table 2 indicates stationary in the first difference I (1) for olive oil prices. The numbers in brackets are the critical test values at the 1% level. Model I includes the constant only, and Model II includes both the constant and the trend.

In order to detect the possibility of non-constant variance in the model errors, the heteroskedasticity test with ARCH standard was performed. Table 3 shows the results of the probabilistic values related to the null hypothesis (homoscedasticity presence in the returns), which was rejected. Thus, it was necessary to adjust a model to correct the interference of the autoregressive conditional heteroscedasticity processes. In order to detect the serial autocorrelation problem, the Breusch and Godfrey (1981) LM test was carried out. The results shown in Table 4 also indicate the presence of serial autocorrelation.

Table 3: ARCH test for homoscedasticity pattern and serial autocorrelation

ARCH test				
	F statistics	P-value	Obs R^2	P-value
Lag 1	4.516	0.034	4.490	0.034
Lag 5	3.293	0.006	16.082	0.006
Lag 10	1.743	0.069	17.176	0.070
Lag 20	0.939	0.536	18.890	0.529
Serial autocorrelation test: Breusch and Godfrey				
F statistics	10.215	P-value	0.000	
Obs.*R^2	19.661	P-value	0.000	

From the unit root test, as well as the sample and partial correlogram analysis, an ARIMA model (p, d, q) was adjusted for the returns series to correct the existing correlation in the errors. The correlogram analysis indicates the presence of autoregressive vectors: order 1, AR (1), and moving average: order 31, MA (31). Another procedure used to eliminate the heteroscedasticity problem was the robust errors assumption. The truncation process, through the covariance matrix, was applied to the model, thus correcting the autocorrelation and heteroscedasticity problem (Newey and West, 1986).

An ARCH (1) adjustment was made for the return series, as, based on the autoregressive and moving average models, this process was the most appropriate, at a significance level of 1%. The newly generated correlograms were analysed and the ARCH tests accepted the null hypothesis of homoscedasticity. To estimate a model that visualises the volatility component in the return series, a selection of GARCH models was performed by comparing the Akaike (AIC), Schwarz (SBC), and Logarithmic likelihood indicators, to obtain the model that best describes the volatility component of the olive oil series. Table 4 shows the estimated model.

The necessary condition for positive variance and weakly stationary implies that the regression parameters are greater than zero. Therefore, the parameter represented by the ARCH is the reaction of volatility, whereas the parameter represented by the GARCH, which is the last parameter, is the persistence of volatility. The sum of the ARCH and GARCH coefficients determine the risks persistence in the returns. For the olive oil commodity, this value was 0.514333 for the fitted GARCH (1.1) model, which indicates a moderate shock on volatility persistence. This means that the olive oil market is not considered to be highly susceptible to shocks caused by price changes.

This result is justified by the fact that this agricultural crop is not produced exclusively by one or just a few countries. The distribution of the production of olive oil among countries is considerable and is expanding (e.g., Brazil, Chile, and Argentina) and this diversification, in turn, mitigates price volatility. The results obtained show that the growing of olive trees is more stable than the growing of cultivations such as palm oil, rapeseed oil, and soybean oil, as pointed out by the research of Ab Rahman et al. (2007), Busse et al. (2010), and Manera et al. (2013), respectively.

It is therefore perceived that the olive oil crop is not strongly susceptible to a shock, which tends to dissipate rapidly, that is

Table 4: Performance comparison among the tested volatility models

Olive oil - conditional variance	GARCH (1.1)**	GARCH (1.2)	GARCH (2.1)	GARCH (2.2)
C	0.000962 (0.0000)	0.000944 (0.0000)	0.000716 (0.1048)	0.001971 (0.0000)
ARCH (1)	0.214803 (0.0002)	0.212599 (0.0002)	0.218473 (0.0002)	0.208463 (0.0001)
ARCH (2)	-	-	−0.054155 (0.5885)	0.210067 (0.0000)
GARCH (1)	0.299530 (0.0015)	0.286586 (0.1076)	0.474099 (0.1425)	−0.548380 (0.0141)
GARCH (2)	-	0.023743 (0.8686)	-	0.123247 (0.1899)
Durbin-Watson stat	2.084176	2.085063	2.086575	2.125263
Akaike info criterion	−3.452266	−3.447876	−3.448313	−3.461834
Schwarz criterion	−3.396917	−3.383303	−3.383739	−3.388036
Log likelihood	772.4031	772.4285	772.5255	776.5272

to say, that the process of reversion to the average is quick. The results are encouraging for new producers, e.g. Brazil, as olive oil is a food product that presents greater price stability, thus inspiring confidence among new producers.

In spite of the moderate shock of volatility persistence, interesting alternatives exist for increasing the revenue of producers of olive oil. These actions are important, as they increase an olive grove's return, and furthermore, they mitigate the risks to producers, which makes the production of olive oil more advantageous to farmers. Azbar et al. (2004) study olive waste management possibilities. According to these authors, treatment and disposal alternatives of olive oil mill waste increase the economic viability of such a segment.

4. CONCLUSION

This paper, while not ignoring the importance of environmental and socio-economic conditions specific to each region, specifically discusses olive oil price volatility. The analysis of the behaviour of serial agricultural prices is of fundamental economic importance, as large oscillations increase the degree of uncertainty of economic agents and lead to financial losses. In this way, volatility analysis is a risk-minimising mechanism of fundamental importance (Engel and Patton, 2001).

In order to capture the terms of conditional volatility and to identify the reaction mechanism and persistence against shocks, the ARCH and GARCH models were estimated for olive oil (extra-virgin, with maximum acidity of 1%) return series, which was characterised by the process of autoregressive conditional heteroscedasticity. The sum of the reaction coefficients (ARCH) with the volatility persistence coefficient (GARCH), which defines whether the risks persist in the series of returns, resulted in values close to 0.5, which indicates that volatility shocks in prices, will not last for a long time.

This means that changes in levels of olive oil production represent low uncertainty with regards to price changes, due to the weight of the large Mediterranean olive oil producing countries. The volatility and price reaction of the main vegetable oils in the face of positive and negative supply and demand shocks are important parameters for making decisions regarding public policies and for the formulation of private investment in the field of agriculture. Protecting producers and agents involved in the supply chain of olive oil is extremely important, as this sector generates employment and income, as well as quality of life by virtue of its consumption, as postulated by Beauchamp et al. (2005) and Lybbert and Elabed (2013). Finally, the heterogeneity of objectives and effects gives rise to recommending a socio-technical approach to support the development of a policy to incentivise olive oil production (Bana e Costa et al., 2014). The integration of local agriculture in poverty-stricken areas into global markets, such as the olive oil market, requires an integrated policy to mitigate various barriers, including high transaction costs, lack of knowledge of modern agricultural production techniques, or difficulties in accessing capital.

5. ACKNOWLEDGMENTS

The authors are particularly grateful to Capes, CNPq and Fapemig for technical support.

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