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SUSTAINABLE VERSUS CONVENTIONAL OLIVE OIL PRODUCTION IN MEDITERRANEAN COUNTRIES: A PANEL DATA ANALYSIS

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Abstract

This study examines the impact of conventional and sustainable olive oil production methods on export levels in ten Mediterranean countries from 2011 to 2022. Using panel-corrected standard errors (PCSE) and feasible generalized least squares (FGLS), the analysis explores relationships between export quantity, production volume, average annual rainfall, and export levels. The countries are divided into two sub-panels: conventional and sustainable practices. Results reveal a significant positive relationship between export quantity and export levels. In the sustainable sub-panel, the production volume and export relationship are positive but insignificant, while in the conventional sub-panel, it is negative and insignificant. Average annual rainfall positively influences export levels in the conventional panel but has an insignificant effect in the sustainable panel. The study recommends adopting sustainable practices to enhance export levels due to their positive economic and environmental outcomes.
Keywords: *Conventional Production, Mediterranean Region, Olive Oil Exports, Panel Data Analysis, Sustainable Practices*
JEL codes: *C32, Q56, O13*

1. Introduction

Global olive oil production reached a record 19.3 million tons in 2023 and is expected to continue growing, according to World Population Review (2024). This surge, driven by increasing health awareness and global population growth, poses challenges and opportunities for Mediterranean countries, which produce over 90% of the world's olive oil. Leading producers include Spain, Italy, and North African nations like Algeria and Egypt (Table 1). The global olive oil market size is anticipated to reach USD 33.12 billion by 2030, expanding at a 5.2% CAGR from 2023 to 2030, according to a report by Markets Insights Company (2023). As a result, this robust production represents an economic activity of considerable importance for the region. In 2022, the olive oil sector contributed roughly $2.8 billion annually to Spain's economy (Market Insights Company, 2022). Italy's exports are valued at $1.5 billion (Trend Economy, 2022), Tunisia's at over $801 million (Statista, 2023).

Table 1. Olive Oil Production Volumes in Mediterranean Countries

Rank	Country	Production Volume (Tonnes)
1	Spain	1,300,000
2	Italy	600,000
3	Greece	300,000
4	Turkey	250,000
5	Morocco	150,000
6	Portugal	120,000
7	Tunisia	100,000
8	Algeria	80,000
9	Egypt	70,000
10	Syria	60,000

Source: World Population Review.

Beyond its economic importance, the olive oil industry plays a critical role in achieving Sustainable Development Goals such as No Poverty (SDG 1) and Zero Hunger (SDG 2). Studies by Iofrida et al. (2020); Parrilla-González and Ortega-Alonso (2021); González and Alonso (2022), highlight its potential to generate income and employment in rural areas where poverty is prevalent. Additionally, the Mediterranean's unique climate benefits olive cultivation, though it faces challenges from climate change Cardoni and Mercado-Blanco (2023); Zagaria et al. (2023). At the same time, the Intergovernmental Panel on Climate Change (IPCC, 2023) has acknowledged that rising temperatures and shifting precipitation patterns, central to climate change, are having a varied impact on the region. Besides that, as noted by Fraga et al. (2020), climate forecasts for the Mediterranean predict a decrease in precipitation, reducing soil moisture levels, and an increase in temperatures. Furthermore, the frequency of extreme weather events, such as droughts and frequent wildfires, is set to rise, further testing the resilience and capacity of the region's agricultural sector.

Responding to climate challenges, Euro-Mediterranean countries adopt sustainable olive oil production practices, while MENA nations maintain traditional methods. This has fueled academic debate, with some researchers highlighting the environmental and economic benefits of sustainable approaches such as Michalopoulos et al. (2020); Fernandez-Lobato et al. (2021); Lombardo et al. (2021); Ncube et al. (2022) . Conversely, Fraga et al. (2020); Haddad et al. (2020); Maesano et al. (2021); Al-Qodah et al. (2022); Morelli (2022), support the enduring significance of conventional approaches, highlighting their cultural and environmental value and the practical difficulties of modernizing in contexts with limited resources. However, no study has directly compared the economic outcomes of these contrasting approaches using a comprehensive panel data analysis across Mediterranean countries. However, no study has directly compared the economic outcomes of these contrasting approaches using a comprehensive panel data analysis across Mediterranean countries. Therefore, this study aims to address the fundamental question: Can sustainable practices in olive oil production deliver better economic benefits than traditional methods in Mediterranean countries? The central hypothesis is that the shift towards sustainable development practices has led to improved economic and environmental outcomes in the olive oil sector compared to the continued use of conventional practices.

This study investigates the economic outcomes of sustainable versus traditional olive oil production practices in ten Mediterranean countries, analysing export volumes, production levels, and rainfall from 2011 to 2022. Employing PCSE and FGLS methods, we compare countries embracing sustainable practices (Spain, Italy, Greece, Türkiye, Portugal) with those relying on conventional methods (Algeria, Morocco, Egypt, Tunisia, Syria). This analysis contributes to the debate on sustainable agriculture by examining its impact on economic performance and export competitiveness within the context of Mediterranean olive oil production and growing environmental concerns. The study contributes significantly to agricultural economic literature by applying econometric tools to assess the ongoing debate over sustainability in Mediterranean olive oil production. By comparing aspects like productivity and economic profitability, it offers insights valuable to policymakers and industry stakeholders, enhancing understanding of sustainable practices' efficacy and potential. The study contributes significantly to agricultural economic literature by applying econometric tools to assess the ongoing debate over sustainability in Mediterranean olive oil production. By comparing aspects like productivity and economic profitability, it offers insights valuable to policymakers and industry stakeholders, enhancing understanding of sustainable practices' efficacy and potential.

2. Literature Review

Olive oil production is crucial to the Mediterranean economy, impacting social, economic, and environmental sustainability. It boosts exports, creates jobs, and supports economic growth, showcasing its regional importance (Klonaris & Agiangkatzoglou, 2018). Despite its significance, there's ongoing debate about the benefits of sustainable versus traditional production methods, with mixed findings in existing research leaving the best approach undecided.

On one side of the debate, Conventional olive farms, showcasing traditional, rainfed, low-input methods, often operate on challenging terrains like steep slopes and terraces (Lombardo et al., 2022). These farms enhance biodiversity by preventing soil erosion and contribute significantly to environmental, cultural, and historical contexts. Beaufoy (2001); Loumou and Giourga (2003); Brunori et al. (2018) have offered solutions to reduce the environmental impact of EU olive oil production. Loumou and Giourga (2003) focused on Mediterranean countries, and Brunori et al. (2018) on Italy. Kavallari et al. (2011) analysed factors like GDP and distance affecting olive oil demand in Germany and the UK, linking higher exporter income to increased exports and identifying a positive effect of the Barcelona Agreement on German imports. However, these findings may not generalize across all EU states, indicating that the impact of agreements needs individual evaluation.

Mansour et al. (2018) employed a comparative analysis methodology to contrast sustainable practices with conventional practices in Egypt and Tunisia. The authors compared the factors influencing olive production in Egypt against the strengths of Tunisia's olive oil characteristics. The primary findings indicate that, despite its enormous potential, Egypt faces numerous obstacles. However, by adopting Tunisia's effective strategies and resolving internal issues, Egypt could significantly enhance its olive production and market position. Carbone et al. (2018) identified traditional methods, including place-of-production labels and local markets, as key to Italy's olive oil market. Klonaris and Agiangkatzoglou (2018) noted that Spain dominated global olive production from 2008-2014 using conventional methods and emphasized the importance of assessing Greek virgin olive oil's competitiveness and the policy impact on international trade and consumption. Kashiwagi, Yamna, et al. (2020) noted that countries like Italy, Spain, and France import significant olive oil despite large domestic production, challenging standard trade theories like Heckscher–Ohlin.

Conversely, Godini et al., 2011 highlighted that sustainable olive farms, with their intensive, market-oriented production, are more cost-effective and environmentally friendly than traditional groves due to higher yields and lower costs per kilogram. While sustainable olive oil farms may not yield high profits, they offer significant benefits like improved population well-being and reduced environmental damage (Duarte et al., 2008; Palese et al., 2013). Notably, countries like Turkey and Tunisia significantly boosted olive oil production and market share through adopting new cultivation techniques (National Bank of Greece, 2015). Carbone et al. (2018) analysed Italian olive oil prices, with OLS and panel data model for the Italian olive oil markets during 2012-2014. Finding that consumers increasingly value quality cues like certifications and production methods. The study suggests that sustainable practices can enhance both perceived quality and market value of olive oil. Pehlivanoğlu et al. (2021) demonstrated the importance of production and consumption dynamics in achieving a comparative advantage in olive oil exports, suggesting the potential impact of adopting sustainable practices. Lombardo et al. (2022) proposed a guide for sustainable olive oil supply chains, highlighting strengths and weaknesses in Italian farms across environmental, quality, social, and economic dimensions. The study reveals areas for improvement, such as resource management and environmental impact mitigation.

Several studies have compared the performance of conventional and sustainable olive oil production methods. Iofrida et al. (2020) found that organic olive farming in Italy yields better results, particularly in terms of environmental impact. Arfaoui et al. (2022) analysed Tunisia's olive oil export performance in relation to its competitors, highlighting the influence of European production volatility on Tunisia's market share. Martín-García et al. (2023) compared Spanish conventional and organic olive farms, revealing that while conventional farms are more productive, Common Agricultural Policy subsidies contribute to greater profitability and resilience for organic farms. Despite its benefits, olive oil production poses environmental risks. Intensive practices in some sustainable farms can lead to greater environmental impact compared to traditional methods (Beaufoy, 2001). Olive mill wastewater presents a significant pollution threat if untreated (Dermeche et al., 2013). Climate change further exacerbates these challenges, with potential shifts in olive tree distribution and increased vulnerability of rain-fed groves in arid regions (Gambella et al. 2021; Mairech et al., 2021).

Drawing from this concise synopsis of prior research in our area of interest, we discern multiple lacunae, which can be summed up as follows. First, no previous research has tried to analyse the relationship between the exports of olive oil, the production volume of olive oil, the quantity of olive oil exports and the environmental variable of average annual rainfall in 10 major Mediterranean olive oil-producing countries. Subsequently, no prior studies had distinguished between conventional and sustainable agriculture groups. Lastly, there are not many studies that use panel data from these Mediterranean nations that produce olive oil. While the reviewed studies offer valuable insights into the economic, trade and environmental aspects of olive oil production, a gap persists in directly comparing the economic outcomes of sustainable versus traditional practices using panel data in Mediterranean countries. Our study aims to bridge this gap by analysing data on yields, and sustainability metrics in Mediterranean countries, thus contributing a more focused and comprehensive understanding of the economic implications of sustainable and traditional olive oil production practices. The present study provides a new perspective by systematically comparing productivity and economic profitability under both sustainable and traditional practices. Moreover, by employing panel data analysis, this study contributes to the ongoing dialogue about the future of olive oil production driven comparison of sustainable and traditional practices, based on econometric techniques and methods.

3. Research Methods

3.1. Methodology

Sustainable agricultural practices aim to preserve the environment, ensure economic viability, and achieve social justice. Using the Resource-Based View (RBV) theory (Barney, 1991). We classify ten Mediterranean countries into two groups: sustainable and traditional practices. This theory suggests that competitive advantage derives from managing resources that are valuable, rare, and hard to replicate. Spain, Italy, and Portugal use advanced technologies and sustainable methods like organic farming and water management, enhancing product quality and sustainability. In contrast, Algeria, Morocco, and the Syrian Arab Republic rely on traditional methods due to technological and investment constraints. Greece and Egypt are gradually shifting towards sustainable practices, aligning with global trends. Therefore, we classify in Table 2 ten Mediterranean countries into two subpanels. Classification criteria include the extent of organic farming, policies promoting sustainable agriculture, and data from reputable sources (e.g., FAO, EU). Peer-reviewed studies and industry reports also inform this classification.

Table 2. Two Subpanel Cross-Sections

Sustainable Practices Group	**Traditional Practices Group**
Spain is known for modern and intensive olive farming techniques, with a significant shift towards sustainable practices, including water management and organic farming (Fernández-Lobato et al., 2024).	Algeria is using mostly traditional practices with slow adoption of sustainable methods in agriculture sector (Ariom et al., 2022)
Italy has a mix of traditional and modern practices but has been moving towards more sustainable, organic olive oil production (Cappelli et al., 2023)	Morocco has a mix of traditional and modern practices, but with a significant portion of its agriculture still leaning towards traditional methods (Lago-Olveira et al., 2024).
Portugal is similar to Spain and Italy, while it is adopting sustainable practices, especially in its newer olive farms (Benitez-Cabello et al., 2023)	Although Tunisia is interested in sustainability, the country's agricultural sector still largely uses traditional methods. (Benabdelkader et al., 2021).
Greece has a strong tradition of producing olive oil using traditional methods, but fortunately there is a growing trend towards organic and sustainable practices. (Rezazga et al., 2024)	Egypt has a primarily traditional agricultural practices with gradual moves towards modernization and sustainability (Zagaria et al., 2023).
Turkey has several areas of both traditional and modern agriculture, with increasing interest in sustainable practices in its agricultural sectors (DEMİRTAŞ & LİMAN, 2023).	Syrian Arab Republic has relied on conventional farming methods, despite the ongoing conflict (Sulaiman et al., 2023)

Source: Compiled by authors’ from various sources.

3.2. Data and Variables

This used two subpanel models and a panel model for these countries from 2011 to 2022. Panel models combine time series from multiple entities, increasing data variability, reducing collinearity among variables, and improving econometric estimates' efficiency. The study focuses on the economic benefits of sustainable versus traditional olive oil production practices. Variables analysed include olive oil exports (Exp), production volume (Pro), export quantity (ExpQ), and average annual rainfall (Rain). Table 3 provides detailed definitions, units, and sources for each variable, crucial for assessing the economic outcomes of different production practices in these Mediterranean countries.

Table 3. Variables Definitions

Variable	Description	Unit	Source
$\mathbf{Exports_{it}}$ (Exp)	The exports of olive oil for country i in year t	Thousand USD	Trend Economy Data
$\mathbf{Production_{it}}$ (Pro)	The production volume of olive oil for country i in year t	Tonnes (t)	The Food and Agriculture Organization (FAO)
$\mathbf{ExportQuantity_{it}}$ (ExpQ)	The quantity of olive oil exports for country i in year t	Tonnes (t)	The Food and Agriculture Organization (FAO)
$\mathbf{Rainfall_{it}}$ (Rain)	The environmental variable of average annual rainfall for country i in year t	Millimeters (mm)	Our World in Data

Source: Compiled by authors' from various sources.

We use exports as the dependent variable because economic theory suggests that both production efficiency and sustainable practices can enhance export value (Auty & Warhurst, 1993). Countries adopting sustainable practices may develop a comparative advantage, leading to increased exports by improving productivity and meeting international market standards (Brondino, 2023). The Export-Led Growth Hypothesis (Jin, 2002) further supports this, suggesting that higher exports drive overall economic growth (Jin, 2002) further supports this, suggesting that higher exports drive overall economic growth. The study also examines the volume of olive oil production as a key independent variable, hypothesizing that sustainable practices can increase production and export capabilities (Amiri & Gerdtham, 2011). This aligns with the Production Function Theory, which includes land, labor, capital, and technology as inputs transformed into outputs (Timmer, 1971; Cornia, 1985).

Moreover, the quantity of olive oil exports measures the physical volume of exports, helping to distinguish price and quantity effects on revenues. If sustainable practices lead to higher export values without increasing quantities, it suggests a premium for sustainably produced olive oil. This aligns with sustainable development principles (Stempfle et al., 2021; Blissett, 2023) and comparative advantage theory, where nations benefit from specializing in efficient production (Ruffin, 2002; Siddiqui, 2018). Efficient resource use in olive oil production reflects this advantage resources (Tomislav, 2018). Porter's Competitive Advantage Theory further supports developing competitive industries through unique resources and innovations (Huggins & Izushi, 2015). Also, this study incorporates average annual rainfall as a control variable to account for the significant influence of environmental and climatic factors on olive oil production. Rainfall variability directly impacts olive oil yield, and controlling for this factor allows for a more accurate assessment of the effects of sustainable versus traditional agricultural practices on economic outcomes (Rodrigo-Comino et al., 2021). This approach aligns with the Resource-Based View theory, emphasizing the importance of natural resources in achieving competitive advantage, and highlights the relevance of sustainable practices in addressing environmental challenges specific to the Mediterranean region (Buchana, 2023).

3.3. Model Specification

Analysing panel data requires addressing issues like inconsistency, bias in estimators, heteroskedasticity, and autocorrelation. This study employs Panels Corrected Standard Errors (PCSE) and Feasible Generalized Least Squares (FGLS) instead of fixed or random effects models due to the complex error structures often present in panel data (Beck & Katz, 2012; Pesaran, 2015). For this reason, we ought to use models with the appropriate standard errors. Thus, the basic OLS assumptions about homoscedasticity and no autocorrelation are not met as follows:

$$E(e_{i,t}) \neq 0 \tag{1}$$

$$Variance(e_{i,t}) \neq \sigma^2 \tag{2}$$

$$Covariance(e_{i,t};\ e_{j,s}) \neq 0 \tag{3}$$

Also, the matrix of variance-covariance can be written as following:

$$E(ee') = \Omega_{ee'} \neq \begin{bmatrix} \sigma^2 * I & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sigma^2 * I \end{bmatrix} \tag{4}$$

The non-respect of these assumptions about the error process may lead to bias and inconsistent estimators. Consequently, we must verify the assumptions made regarding no error autocorrelation, normality, and homoskedasticity. This is crucial to prevent our results from being statistical artefacts. The basic panel model can be written as follow:

$$Y_{i,t} = X_{i,t}\beta + \varepsilon_{i,t} \tag{5}$$

Where $i = 1 \dots N\ ;\ t = 1 \dots T$

$X_{i,t}$ is a vector of one or more (k) exogenous variables in unit (i) and time (t), while β is estimators' vector, and $Y_{i,t}$ is vector of endogenous variable in unit (i) and time (t). This panel model has a covariance matrix of the standard errors $\Omega_{ee'}$, but it is tough to estimate this model with a classical OLS in panel data, because the panel model's error process might be more intricate than that of cross-sectional or time-series models(Stimson, 1985).

We can estimate the eq. 5 with Generalised Least Squares (GLS), no matter how complicated the error process is, as long as the covariance matrix of those errors is known $\Omega_{ee'}$ (Kmenta, 1986, pp. 16-609). In order to use GLS, we need to transform the eq. 5 with the matrix of overall error covariance to alternative linear equation where such matrix is suitable for OLS estimation (spherical). The GLS estimates of β are writing as following:

$$\hat{\beta} = (X'\Omega_{ee'}{}^{-1}X)^{-1}\, X'\Omega_{ee'}{}^{-1}\, Y \tag{6}$$

With the matrix of estimated covariance

$$(X'\Omega_{ee'}{}^{-1}X)^{-1} \tag{7}$$

However, the covariance matrix of the errors $\Omega_{ee'}$ is never known. Thus, to solve this issue Parks (1967) describe the FGLS technique by providing an estimated variance-covariance matrix $\widehat{\Omega}_{ee'}$, which it replaces $\Omega_{ee'}$ in the next formula. FGLS has the same properties as GLS for panel analysis. FGLS method will gives us unbiased estimates of β under very general conditions. The FGLS estimates of β are writing as following:

$$\hat{\hat{\beta}} = (X'\widehat{\Omega}_{ee'}{}^{-1}X)^{-1}\, X'\widehat{\Omega}_{ee'}{}^{-1}\, Y \quad (8)$$

However, in order to use Parks-Kmenta's method, we need (T > N), but, Beck and Katz (2012) doubt about FGLS's performance in finite samples and assert that the technique frequently yields overly optimistic with standard errors. Therefore, the authors recommend applying a traditional OLS estimation technique that accounts for the panel heteroskedasticity, autocorrelation and contemporaneous correlation complications, specifically the PCSEs (Beck & Katz, 2012). Before performing PCSE, we need to eliminate any errors serial correlation. In this procedure, we rely on the square roots of the diagonal terms of $Cov\ (\hat{\beta})$ written as follow:

$$Cov\ (\hat{\beta}) = (X'X)^{-1}\, (X'\Omega_{ee'}X)\ \ (X'X)^{-1} \quad (9)$$

To use FGLS and PCSE effectively, it's crucial to confirm error autocorrelation and heteroskedasticity. Post-estimation tests verify hypotheses, forecast outcomes, analyze residuals, identify outliers, and assess model robustness. They also test the model's sensitivity to data subsets. The Jarque-Bera test checks for residual normality Jarque and Bera (1987). Feng et al. (2020) highlight the importance of testing for heteroskedasticity in panel data. We use panel groupwise heteroskedasticity tests (Baum, 2001) with the “ghxt” command in STATA (Shehata, 2011). The Wooldridge test detects first-order autocorrelation Drukker (2003) introduced the “xtserial” command in STATA, based on the Wooldridge (2010) test for detecting first-order autocorrelation in the errors of a panel data model. This robust method is favored by many researchers for testing panel data autocorrelation because it imposes fewer assumptions about the behavior of heterogeneous individual effects. The test, which relies on residuals from the first-differenced regression of the dependent variable on its lagged values, is designed to detect first-order autocorrelation.

The study's model can be described as follows:

$$Exp_{it} = \beta_0 + \beta_1 Pro_{it} + \beta_2 ExpQ_{it} + \beta_3 Rain_{it} + \varepsilon_{it} \quad (10)$$

Where β_0 is the intercept, while $\beta_1, \beta_2, \beta_3$ are the coefficients of the Pro, ExpQ and Rain respectively, $\boldsymbol{v_{it}}$ is the error term.

4. Empirical analysis

We present the estimation results of the panel model for ten Mediterranean countries using Panel-Corrected Standard Errors (PCSE) and Feasible Generalized Least Squares (FGLS) methodologies as follows:

Table 4 shows that our model is statistically robust, with strong and significant squared R and Fisher statistics. Post-estimation tests yield mixed outcomes: the Jarque-Bera test confirms normal residual distribution, and the Wooldridge test shows no serial correlation, validating the model's reliability. However, panel groupwise heteroskedasticity tests detect heteroskedasticity, necessitating adjustments in our estimations. The positive and significant intercept in both PCSE and FGLS models at the 1% level indicates a robust relationship between baseline agricultural productivity and export volumes. A 1% increase in the constant term correlates with a substantial increase in exports, highlighting the positive impact of improved agricultural systems on export levels.

Table 4. Estimation of the Panel Model with Ten Mediterranean Countries

Variables	PCSE		FGLS
	Coefficient (prob)		Coefficient (prob)
Intercept	7.952*** (0)		7.960***(0)
Pro	-0.045* (0.076)		-0.046***(0)
ExpQ	1.014*** (0)		1.014***(0)
Rain	0.107*** (0)		0.106***(0)
R^2	0.994		
Fisher	6405.778*** (0)		
Post Estimation Tests			
Jarque-Bera test	1.394 (0.498)		
AC Test[1]	3.323 (0.1016)		
Hetero Test[2]	LM=32.61*** (0)	LR= 25.44*** (0.002)	Wald = 66.62*** (0)

Source: Authors' estimates using STATA 17
Note: PCSE estimated with panel-level heteroscedasticity and correlated across panels, while FGLS estimated with heteroskedastic with cross-sectional correlation. "***", '**', '*' refers to the confidence interval at 99%,95%, and 90% level.

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Table 5. Estimation of The Two Subpanel Models

	Sustainable Practise			Conventional Practise		
Variables	PCSE		FGLS	PCSE		FGLS
	Coefficient (prob)		Coefficient (prob)	Coefficient (prob)		Coefficient (prob)
Intercept	7.28*** (0)		8.11*** (0)	8.38*** (0)		8.088*** (0)
Pro	0.026 (0.527)		0.03 (0.44)	-0.07 (0.282)		-0.043 (0.463)
ExpQ	0.981*** (0)		0.95*** (0)	1.007*** (0)		1.00*** (0)
Rain	0.14 (0.195)		0.07 (0.516)	0.08*** (0.006)		0.09*** (0)
Rho	0.440			…		
R^2	0.995			0.9923		
Fisher	3438.12*** (0)			2405.58*** (0)		
Post Estimation Tests						
J-B test	2.503 (0.2861)			4.641 * (0.0982)		
AC Test	106.040*** (0.0005)			1.207 (0.3335)		
Hetero Test	LM=3.74 (0.442)	LR= 3.86 (0.425)	Wald = 5.384 (0.371)	LM=12.34** (0.015)	LR= 9.36* (0.053)	Wald = 10.39* (0.065)

Source: Authors' estimates using STATA 17.
Note1: For panel model of sustainable practise, there is autocorrelation of errors, therefore the PCSE estimated with common AR (1), while FGLS estimated with panels homoscedastic and panel-specific AR (1). For conventional Panel, there is heteroscedasticity of errors, thus PCSE estimated with linear regression, and heteroskedastic panels corrected standard errors, while FGLS estimated with heteroskedastic and no autocorrelation
Note 2: "***", '**', '*' refers to the confidence interval at 99%,95%, and 90% level.

Contrastingly, the Production_{it} (Pro) variable is negative and significant, suggesting that increased production volume reduces export levels by 0.045% (PCSE) and 0.046% (FGLS), implying that production volume does not support olive oil exports. This finding contradicts the export-led growth hypothesis. The $\text{ExportQuantity}_{it}$ (ExpQ) variable is positive and significant at the 1% level, indicating that a 1% increase in export quantity boosts export levels by 1.014%. This supports the principle that nations should focus on producing and exporting goods where they have a comparative advantage. Likewise, Rainfall_{it} (Rain) variable has a positive and significant coefficient at the 1% level; therefore, a 1% increase in rainfall will increase the export level by 0.107% in PCSE and 0.106% in FGLS, respectively. This effect is observed regardless of the farming techniques employed, indicating that variations in rainfall significantly influence annual fluctuations in olive oil production. Consequently, we demonstrate that rainfall positively affects the level of olive oil exports, with similar climatic and environmental conditions contributing to this result.

Table 5 compares sustainable and conventional subpanels, highlighting differences in trade and sustainability. Both models are statistically robust, with significant R-squared and Fisher statistics. For the sustainable practices model, the Jarque-Bera test confirms normality of residuals, while the Wooldridge test indicates serial correlation, but no heteroskedasticity is detected. The positive and significant intercept at the 1% level suggests that a 1% increase in the constant term raises olive oil exports by 7.28% in the PCSE model and 8.11% in the FGLS model. This indicates that sustainable agricultural practices significantly boost the baseline level of productivity and export volumes. Although the Pro variable is positive, it is not statistically significant, indicating that the production volume does not directly support export growth in these countries. The ExpQ variable is positive and significant at the 1% level, implying that a 1% increase in export quantity results in an approximate 1% increase in export levels. This demonstrates that sustainable practices help firms enter and thrive in the international market, underscoring the principle of comparative advantage. The Rain variable, while positive, is not significant, suggesting that rainfall has a limited impact on exports in sustainably practicing countries.

Conversely, for the conventional practices model, the Jarque-Bera test confirms normality of residuals and no serial correlation is detected by the Wooldridge test; however, heteroskedasticity is present. The positive and significant intercept at the 1% level indicates that a 1% increase in the constant term raises export levels by 8.38% in the PCSE model and 8.088% in the FGLS model. This implies that conventional farming systems still significantly contribute to productivity and export intensity. However, the Pro variable is negative and insignificant, suggesting that increased production volumes do not support export growth, possibly due to inefficiencies or lower productivity levels in conventional practices. The ExpQ variable is positive and significant at the 1% level, indicating that a 1% increase in export quantity boosts export levels by approximately 1%, similar to the sustainable model. The Rain variable is positive and significant, demonstrating that rainfall variability significantly influences export levels in conventionally practicing countries.

These findings highlight a complex interplay between agricultural practices, production levels, and environmental conditions in shaping the olive oil export landscape in Mediterranean countries. Sustainable practices are shown to enhance export levels and productivity, aligning with the export-led growth hypothesis. In contrast, conventional practices exhibit a negative impact on production volume and export potential, suggesting inefficiencies. Both models underline the necessity for tailored agricultural strategies to boost resilience and competitiveness.

5. Conclusion

The foundational premise of conventional international trade theories posits that nations tend to specialize and excel in producing and exporting goods for which they have a comparative advantage. This principle is vividly illustrated by the olive oil trade in Mediterranean countries, However, with the specter of climate change posing a formidable challenge, Mediterranean nations, particularly those in Europe, face the risk of losing their competitive edge. In response, these countries are increasingly embracing technologies and principles rooted in sustainable development, including efficiency, optimal resource utilization, waste reduction, and environmental protection. Conversely, countries in the MENA region acknowledge their limited capacity to adopt such measures. In light of these developments, our study explored the complex interplay between the quantities of olive oil exported, production volumes, and the impact of average annual rainfall on export levels across ten Mediterranean countries from 2011 to 2022. Employing Panel-Corrected Standard Errors (PCSE) and Feasible Generalized Least Squares (FGLS) methodologies, our analysis encompassed a panel of major Mediterranean olive oil-producing nations. These countries were categorized into two distinct groups based on their agricultural practices: conventional versus sustainable.

The findings from an analysis of ten Mediterranean olive oil-producing countries indicate that the Production_{it} (Pro) variable exhibits a negative and significant impact at the 10% level for PCSE and at the 1% level for FGLS. Conversely, the $\text{ExportQuantity}_{it}$ (ExpQ) variable demonstrates a positive and statistically significant coefficient at the 1% level, suggesting that a 1% increase in this variable leads to an increase in the export level by 1.014% for both PCSE and FGLS methodologies. Similarly, the Rainfall_{it} (Rain) variable shows a positive and significant coefficient at the 1% level, indicating that a 1% rise in rainfall results in an increase in the export level by 0.107% in PCSE and 0.106% in FGLS. However, in the two subpanel models, the results reveal a positive and significant relationship between the quantity of exports and the level of exports. Furthermore, our investigation establishes that, within the subpanel model focusing on sustainable practices, the relationship between production volume and olive oil exports is positive but not statistically significant. In contrast, within the subpanel model employing conventional methods, this relationship appears negative and also statistically insignificant. Our analysis further demonstrates that average annual rainfall has a positive and significant effect in the subpanel model employing conventional methods. However, in the subpanel model adopting sustainable practices, the impact of average annual rainfall on exports is positive but not statistically significant.

Our study reveals a positive, significant relationship between export quantities and production levels under sustainable practices, contrasted by mixed impacts in conventional models. This highlights the complexity of transitioning to sustainable agriculture. While sustainable practices offer benefits, they require targeted support and adaptation to local conditions. Policy measures to encourage sustainability in the olive oil industry could include:

- Educational programs to enhance farmers' awareness and skills in sustainable practices.
- Support for young farmers and the digitalization of agriculture to facilitate modern, eco-friendly production methods.
- Investment in research to optimize the use of natural resources and reduce environmental impacts through integrated farming systems.

Future research should aim to broaden the scope of analysis by incorporating more variables that affect international competition, thereby offering a more comprehensive understanding of the dynamics at play in the global olive oil market.

References

Al-Qodah, Z., Al-Zoubi, H., Hudaib, B., Omar, W., Soleimani, M., Abu-Romman, S., & Frontistis, Z. (2022). Sustainable vs. Conventional Approach for Olive Oil Wastewater Management: A Review of the State of the Art. *Water*, *14*(11), 1695. https://doi.org/10.3390/w14111695

Amiri, A., & Gerdtham, U.-G. (2011). Relationship between exports, imports, and economic growth in France: evidence from cointegration analysis and Granger causality with using geostatistical models. https://mpra.ub.uni-muenchen.de/34190/

Arfaoui, M., Erraach, Y., & Boudiche, S. (2022). The performance of the Tunisian olive oil exports within the new distribution of world demand. *New Medit*, *21*(02), 17-30. https://doi.org/10.30682/nm2202b

Ariom, T. O., Dimon, E., Nambeye, E., Diouf, N. S., Adelusi, O. O., & Boudalia, S. (2022). Climate-Smart Agriculture in African Countries: A Review of Strategies and Impacts on Smallholder Farmers. *Sustainability*, *14*(18), 11370. https://doi.org/10.3390/su141811370

Auty, R., & Warhurst, A. (1993). Sustainable development in mineral exporting economies. *Resources Policy*, *19*(1), 14-29. https://doi.org/10.1016/0301-4207(93)90049-s

Baum, C. F. (2001). Residual Diagnostics for Cross-section Time Series Regression Models. *The Stata Journal: Promoting communications on statistics and Stata*, *1*(1), 101-104. https://doi.org/10.1177/1536867x0100100108

Barney, J. (1991). Firm resources and sustained competitive advantage. Journal of management, 17(1), 99-120.

Beaufoy, G. (2001). *The environmental impact of olive oil production in the European Union: practical options for improving the environmental impact*. Commission of the European Communities, Brussels, Belgium. http://ec.europa.eu/environment/agriculture/pdf/oliveoil.pdf

Beck, N., & Katz, J. N. (2012). What To Do (and Not to Do) with Time-Series Cross-Section Data. *American political science review*, *89*(3), 634-647. https://doi.org/10.2307/2082979

Benabdelkader, M., Saifi, R., & Saifi, H. (2021). Sustainable Agriculture in Some Arab Maghreb Countries (Morocco, Algeria, Tunisia). *Agro-Environmental Sustainability in MENA Regions*, 233-261. https://doi.org/https://doi.org/10.1007/978-3-030-78574-1_10

Benitez-Cabello, A., Delgado, A. M., & Quintas, C. (2023). Main Challenges Expected from the Impact of Climate Change on Microbial Biodiversity of Table Olives: Current Status and Trends. *Foods*, *12*(19), 3712. https://doi.org/10.3390/foods12193712

Blissett, K. A. (2023). *Indicators of sustainability in Mediterranean olive value chains: Building knowledge for the transition to sustainable food systems Thesis conducted within the frame of the SNF-funded project "Deliberative diets: Connecting producers and consumers to value the sustainability of Swiss food system scenarios"* Norwegian University of Life Sciences]. https://hdl.handle.net/11250/3108886

Brondino, G. (2023). Fragmentation of production, comparative advantage, and the Heckscher-Ohlin theory. *Review of Political Economy*, *35*(3), 803-822. https://doi.org/10.1080/09538259.2021.1977540

Brunori, E., Salvati, L., Antogiovanni, A., & Biasi, R. (2018). Worrying about 'vertical landscapes': Terraced olive groves and ecosystem services in marginal land in central Italy. *Sustainability*, *10*(4), 1164. https://doi.org/10.3390/su10041164

Buchana, Y. (2023). Eco-innovation and agricultural sustainability: empirical evidence from South Africa's agricultural sector. *Innovation and Development*, 1-20. https://doi.org/10.1080/2157930X.2023.2268913

Cappelli, A., Lupori, L., & Cini, E. (2023). Should extra virgin olive oil production change the approach? A systematic review of challenges and opportunities to increase sustainability, productivity, and product quality. *Journal of Agricultural Engineering*, *54*(1). https://doi.org/10.1080/2157930X.2023.2268913

Carbone, A., Cacchiarelli, L., & Sabbatini, V. (2018). Exploring quality and its value in the Italian olive oil market: a panel data analysis. *Agricultural and food economics*, *6*, 1-15. https://doi.org/10.1186/s40100-018-0102-8

Cardoni, M., & Mercado-Blanco, J. (2023). Confronting stresses affecting olive cultivation from the holobiont perspective. *Frontiers in Plant Science*, *14*.

Economic Complexity. (2021). *Syria Economic* https://oec.world/en/profile/country/syr

Cornia, G. A. (1985). Farm size, land yields and the agricultural production function: An analysis for fifteen developing countries. *World development*, *13*(4), 513-534. https://doi.org/10.1016/0305-750x(85)90054-3

De Luca, A. I., Iofrida, N., González De Molina, M. L., Spada, E., Domouso, P., Falcone, G., Gulisano, G., & García Ruiz, R. (2023). A methodological proposal of the Sustainolive international research project to drive Mediterranean olive ecosystems towards sustainability. *Frontiers in Sustainable Food Systems*, *7*, 1207972. https://doi.org/10.3389/fsufs.2023.1207972

DEMİRTAŞ, B., & LİMAN, K. (2023). THE REFLECTION OF THE SUPPORT POLICIES APPLIED IN OLIVE AND OLIVE OIL TO THE PRODUCERS. *Economics and Administrative Sciences Modern Analysis and Researches*, 137. https://doi.org/10.5281/zenodo.10435905

Dermeche, S., Nadour, M., Larroche, C., Moulti-Mati, F., & Michaud, P. (2013). Olive mill wastes: Biochemical characterizations and valorization strategies. *Process biochemistry*, *48*(10), 1532-1552. https://doi.org/10.1016/j.procbio.2013.07.010

Drukker, D. M. (2003). Testing for serial correlation in linear panel-data models. *The Stata Journal*, *3*(2), 168-177. https://doi.org/10.1177/1536867X0300300206

Duarte, F., Jones, N., & Fleskens, L. (2008). Traditional olive orchards on sloping land: sustainability or abandonment? *J Environ Manage*, *89*(2), 86-98. https://doi.org/10.1016/j.jenvman.2007.05.024

Feng, S., Li, G., Tong, T., & Luo, S. (2020). Testing for heteroskedasticity in two-way fixed effects panel data models. *J Appl Stat*, *47*(1), 91-116. https://doi.org/10.1080/02664763.2019.1634682

Fernandez-Lobato, L., Garcia-Ruiz, R., Jurado, F., & Vera, D. (2021). Life cycle assessment, C footprint and carbon balance of virgin olive oils production from traditional and intensive olive groves in southern Spain. *J Environ Manage*, *293*, 112951. https://doi.org/10.1016/j.jenvman.2021.112951

Fernández-Lobato, L., Ruiz-Carrasco, B., Jurado, F., & Vera, D. (2024). Environmental impact of the most representative Spanish olive oil farming systems: A life cycle assessment study. *Journal of Cleaner Production*, 141169. https://doi.org/10.1016/j.jenvman.2021.112951

Fraga, H., Moriondo, M., Leolini, L., & Santos, J. A. (2020). Mediterranean olive orchards under climate change: A review of future impacts and adaptation strategies. *Agronomy*, *11*(1), 56. https://doi.org/10.3390/agronomy11010056

Gambella, F., Bianchini, L., Cecchini, M., Egidi, G., Ferrara, A., Salvati, L., Colantoni, A., & Morea, D. (2021). Moving toward the north? The spatial shift of olive groves in Italy. *ZEMEDELSKA EKONOMIKA*, *67*(4), 129-135. https://hdl.handle.net/11584/315197

Godini, A., Vivaldi, G., & Camposeo, S. (2011). Sidebar: olive cultivars field-tested in super-high-density system in southern Italy. *California Agriculture*, *65*(1), 39-40. https://doi.org/10.3733/ca.v065n01p39

González, J. A. P., & Alonso, D. O. (2022). Sustainable Development Goals in the Andalusian olive oil cooperative sector: Heritage, innovation, gender perspective and sustainability. *New medit: Mediterranean journal of economics, agriculture and environment= Revue méditerranéenne d'economie, agriculture et environment*, *21*(2), 31-42. https://doi.org/10.30682/nm2202c

Greece, N. B. o. (2015). *Olive oil: establishing the Greek brand* (sectoral report, Issue.

Greene, W. H. (2000). Econometric analysis 4th edition. *International edition, New Jersey: Prentice Hall*, 201-215.

Haddad, B., Gristina, A. S., Mercati, F., Saadi, A. E., Aiter, N., Martorana, A., Sharaf, A., & Carimi, F. (2020). Molecular Analysis of the Official Algerian Olive Collection Highlighted a Hotspot of Biodiversity in the Central Mediterranean Basin. *Genes (Basel), 11*(3), 303. https://doi.org/10.3390/genes11030303

Huggins, R., & Izushi, H. (2015). The Competitive Advantage of Nations: origins and journey. *Competitiveness Review, 25*(5), 458-470. https://doi.org/10.1108/CR-06-2015-0044

Iofrida, N., Stillitano, T., Falcone, G., Gulisano, G., Nicolo, B. F., & De Luca, A. I. (2020). The socio-economic impacts of organic and conventional olive growing in Italy. *New Medit, 19*(1), 117-131. https://doi.org/10.30682/nm2001h

International Olive Council (IOC), (2021). Olive Oil Production Has Tripled. In. www.internationaloliveoil.org

IPCC.(2023).https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM

ISMEA. (2020). https://aecm.eu/wp-content/uploads/2021/01/IT_ISMEA.pdf

Jarque, C. M., & Bera, A. K. (1987). A test for normality of observations and regression residuals. *International Statistical Review/Revue Internationale de Statistique*, 163-172. https://doi.org/10.2307/1403192

Jin, J. C. (2002). Exports and Growth: is the Export-led Growth Hypothesis valid for provincial economies? *Applied economics, 34*(1), 63-76. https://doi.org/10.1080/00036840010025632

Kashiwagi, K., Erraach, Y., Arfa, L., & Zaibet, L. (2020). Growing olive oil export and intra-industry trade in Mediterranean countries: Application of gravity model. *Sustainability, 12*(17), 7027.

Kashiwagi, K., Yamna, E., Arfa, L., & Zaibet, L. (2020). Growing Olive Oil Export and Intra-Industry Trade in Mediterranean Countries: Application of Gravity Model. *Sustainability, 12*(17), 7027. https://doi.org/10.3390/su12177027

Kavallari, A., Maas, S., & Schmitz, P. M. (2011). Examining the determinants of olive oil demand in nonproducing countries: Evidence from Germany and the UK. *Journal of Food Products Marketing, 17*(2-3), 355-372. https://doi.org/0.1080/10454446.2011.548721

Klonaris, S., & Agiangkatzoglou, A. (2018). Competitiveness of Greek virgin olive oil in the main destination markets. *British Food Journal, 120*(1), 80-95. https://doi.org/10.1108/BFJ-07-2016-0331

Kmenta, J. (1986). Elements of econometrics. 2d ed. new york city. In: New York: University of Michigan Press.

Lago-Olveira, S., Ouhemi, H., Idrissi, O., Moreira, M. T., & González-García, S. (2024). Promoting more sustainable agriculture in the Moroccan drylands by shifting from conventional wheat monoculture to a rotation with chickpea and lentils. *Cleaner Environmental Systems*, 100169. https://doi.org/10.1016/j.cesys.2024.100169

Lombardo, L., Farolfi, C., & Capri, E. (2021). Sustainability Certification, a New Path of Value Creation in the Olive Oil Sector: The ITALIAN Case Study. *Foods, 10*(3), 501. https://doi.org/10.3390/foods10030501

Lombardo, L., Farolfi, C., Tombesi, S., Novelli, E., & Capri, E. (2022). Development of a sustainability technical guide for the Italian olive oil supply chain. *Sci Total Environ, 820*, 153332. https://doi.org/10.1016/j.scitotenv.2022.153332

Loumou, A., & Giourga, C. (2003). Olive groves:``The life and identity of the Mediterranean''. *Agriculture and human values, 20*, 87-95. https://doi.org/10.1023/A:1022444005336

Maesano, G., Chinnici, G., Falcone, G., Bellia, C., Raimondo, M., & D'Amico, M. (2021). Economic and environmental sustainability of olive production: A case study. *Agronomy, 11*(9), 1753. https://doi.org/10.3390/agronomy11091753

Mairech, H., Lopez-Bernal, A., Moriondo, M., Dibari, C., Regni, L., Proietti, P., Villalobos, F. J., & Testi, L. (2021). Sustainability of olive growing in the Mediterranean area under future climate scenarios: Exploring the effects of intensification and deficit irrigation. *European Journal of Agronomy*, *129*, 126319. https://doi.org/10.1016/j.eja.2021.126319

Mansour, T. G., Hassan, H. B., Abd El-Ghani, S. S., & Khalil, E. (2018). The Tunisian experience in olive production and marketing and how to benefit from it in the Egyptian case. *Middle East J*, *7*(3), 1154-1164.

Market_Insights_company. (2022). *Olive Oil Market Size by Type (Extra Virgin, Virgin, Pure/Refined, and Others), By End-user (Foodservice/HoReCa, Household/Retail, Food Manufacturing, and Others), Regions, Global Industry Analysis, Share, Growth, Trends, and Forecast 2023 to 2032* (FBI107551). t. b. insights. https://www.thebrainyinsights.com/report/olive-oil-market-13494#

Markets, R. a. (2023). *Global Olive Oil Market Size, Share & Trends Analysis Report by Type (Refined, Virgin), Packaging (Bottles, Pouches, Cans), Application, Distribution Channel, Region, and Segment Forecasts, 2023-2030*. R. a. Markets. https://www.researchandmarkets.com/report/olive-oil#product--toc

Martín-García, J., Gómez-Limón, J. A., & Arriaza, M. (2023). Conventional versus organic olive farming: which has a better economic performance? *Agricultural and food economics*, *11*(1), 51. https://doi.org/10.1080/08974438.2019.1599763

Michalopoulos, G., Kasapi, K., Koubouris, G., Psarras, G., Arampatzis, G., Hatzigiannakis, E., Kavvadias, V., Xiloyannis, C., Montanaro, G., & Malliaraki, S. (2020). Adaptation of Mediterranean olive groves to climate change through sustainable cultivation practices. *Climate*, *8*(4), 54. https://doi.org/10.3390/cli8040054

Morelli, M. G. (2022). The role of tradition in business model innovation: a multiple case study in the Italian olive oil family business. https://tesi.luiss.it/id/eprint/35447

Ncube, A., Fiorentino, G., Panfilo, C., De Falco, M., & Ulgiati, S. (2022). Circular economy paths in the olive oil industry: a Life Cycle Assessment look into environmental performance and benefits. *The International Journal of Life Cycle Assessment*, 1-21. https://doi.org/10.1007/s11367-022-02031-2

Othman, F. B., Fadhel, A., & Balghouthi, M. (2022). Sustainable olive-oil mill wastewater treatment by distillation using a parabolic trough solar collector. *Journal of Water Process Engineering*, *48*, 102947. https://doi.org/10.1016/j.jwpe.2022.102947

Palese, A. M., Pergola, M., Favia, M., Xiloyannis, C., & Celano, G. (2013). A sustainable model for the management of olive orchards located in semi-arid marginal areas: Some remarks and indications for policy makers. *Environmental science & policy*, *27*, 81-90. https://doi.org/j.envsci.2012.11.001

Parks, R. W. (1967). Efficient estimation of a system of regression equations when disturbances are both serially and contemporaneously correlated. *Journal of the American Statistical Association*, *62*(318), 500-509. https://doi.org/10.1080/01621459.1967.10482923

Parrilla-González, J. A., & Ortega-Alonso, D. (2021). Dimensions of social innovation in agricultural cooperatives: A model applied to the Spanish olive oil industry. *New Medit: Mediterranean Journal of Economics, Agriculture and Environment= Revue Méditerranéenne d'Economie Agriculture et Environment*, *20*(3). https://hdl.handle.net/10953/1509

Pehlivanoğlu, F., Erarslan, C., & Demir, S. (2021a). Factors affecting competition in olive oil exports: panel data analysis of selected countries. Case study. *Agricultural Economics*, *67*(12), 511-518. https://doi.org/10.17221/494/2020-AGRICECON

Pesaran, M. H. (2015). *Time series and panel data econometrics*. Oxford University Press.

Proietti, P., Nasini, L., Del Buono, D., D’Amato, R., Tedeschini, E., & Businelli, D. (2013). Selenium protects olive (Olea europaea L.) from drought stress. *Scientia Horticulturae*, *164,* 165-171. https://doi.org/10.1016/j.scienta.2013.09.034

Rezazga, A., Ruiz, C., Montanaro, G., Falcone, G., & Koubouris, G. (2024). Driving the Ecological Transition of Agriculture through Voluntary Certification of Environmental

Impacts: An Exploratory Literature Review on the Olive-Oil Sector. *Sustainability*, *16*(3), 1227. https://doi.org/10.3390/su16031227

Rodrigo-Comino, J., Senciales-González, J. M., Yu, Y., Salvati, L., Giménez-Morera, A., & Cerdà, A. (2021). Long-term changes in rainfed olive production, rainfall and farmer's income in Bailén (Jaén, Spain). *Euro-Mediterranean Journal for Environmental Integration*, *6*(2), 58. https://doi.org/10.1007/s41207-021-00268-1

Ruffin, R. (2002). David Ricardo's discovery of comparative advantage. *History of political economy*, *34*(4), 727-748.

Shehata, E. (2011). GHXT: Stata module to compute Panel Groupwise Heteroscedasticity Tests. https://EconPapers.repec.org/RePEc:boc:bocode:s457385

Siddiqui, K. (2018). David Ricardo's comparative advantage and developing countries: Myth and reality. *International Critical Thought*, *8*(3), 426-452. https://doi.org/10.1080/21598282.2018.1506264

Soldati, C., De Luca, A. I., Iofrida, N., Spada, E., Gulisano, G., & Falcone, G. (2023). Ecosystem services and biodiversity appraisals by means of life cycle tools: state-of-art in agri-food and forestry field. *Agriculture & Food Security*, *12*(1), 33. https://doi.org/10.1186/s40066-023-00438-0

Spada, E., Stillitano, T., Falcone, G., Iofrida, N., Gulisano, G., & De Luca, A. I. (2022). Economic sustainability assessment of Mediterranean crops: A comparative Life Cycle Costing (LCC) analysis. *Frontiers in Sustainable Food Systems*, *6*, 1004065. https://doi.org/10.3389/fsufs.2022.1004065

statista. (2023). Export value of olive oil from Tunisia from 2018 to 2023. In. https://www.statista.com: Statista Research Department.

Stempfle, S., Carlucci, D., de Gennaro, B. C., Roselli, L., & Giannoccaro, G. (2021). Available pathways for operationalizing circular economy into the olive oil supply chain: mapping evidence from a scoping literature review. *Sustainability*, *13*(17), 9789. https://doi.org/10.3390/su13179789

Stimson, J. A. (1985). Regression in space and time: A statistical essay. *American Journal of Political Science*, 914-947. https://doi.org/10.2307/2111187

Sulaiman, N., Verner, V., & Polesny, Z. (2023). Socioeconomic Dimensions of Wild Food Plant Use During the Conflict in Syria. *Economic Botany*, *77*(3), 267-281. https://doi.org/10.1007/s12231-023-09579-6

Timmer, C. P. (1971). Using a probabilistic frontier production function to measure technical efficiency. *journal of Political Economy*, *79*(4), 776-794.

Tomislav, K. (2018). The concept of sustainable development: From its beginning to the contemporary issues. *Zagreb International Review of Economics & Business*, *21*(1), 67-94. https://doi.org/10.2478/zireb-2018-0005

Trend Economy. (2022). Olive Oil Imports and Exports 2022. In (2023-12-26 ed.). https://trendeconomy.com/: TrendEconomy.

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. MIT press.

World Population Review. (2024). country-rankings/olive-oil-production-by-country. Available in: https://worldpopulationreview.com/

Zagaria, C., Schulp, C. J., Malek, Ž., & Verburg, P. H. (2023). Potential for land and water management adaptations in Mediterranean croplands under climate change. *Agricultural Systems*, *205*, 103586. https://doi.org/10.1016/j.agsy.2022.103586

[1] - refer to Wooldridge test for autocorrelation in panel data

[2] - refer to panel groupwise heteroscedasticity tests