The Impact of Tourism, Foreign Direct Investment, Trade, Economic Growth, and Renewable Energy on Carbon Emissions: The Case of Mediterranean Countries

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In this study, we examine the influence of international tourism, trade, foreign direct investment, economic growth and renewable energy consumption on CO_2 emissions in 17 Mediterranean countries, spanning the period 1995–2018, by using heterogeneous panel estimation techniques. The findings show that economic growth has a strong impact on carbon dioxide emissions. Our results are in favor of the existence of an inverted U-shaped Environmental Kuznets curve (EKC) in the Mediterranean countries. In addition, the econometric results indicate that international tourism, trade openness, FDI, and renewable energy consumption have a negative impact on carbon dioxide emissions. Moreover, the Dumitrescu and Hurlin panel Granger causality test suggests that there is a two-way causality between CO_2 emissions and the other variables explored (international tourism, openness, FDI, renewable energy consumption and real income) and a one-way causality running from renewable energy consumption and trade openness to real income. Therefore, the development of international trade in the field of renewable energies and the exploitation of these energies in the field of tourism and FDI can be favorable to economic growth and the reduction of carbon dioxide emissions.

Key Words: tourism, trade, foreign direct investment, economic growth, renewable energy, CO_2 emissions

https://doi.org/10.70908/2232-6022/17.313-337

INTRODUCTION

Globally, the massive increase in economic activity has caused a sharp increase in air pollutant emissions and associated mortality. From 1950 to 2019, greenhouse gas emissions increased from 16.13 billion tons to

54.82 billion tons (Jones et al. 2023) representing an average annual growth rate of 2%. In 2016, the World Health Organization (WHO) estimated that air pollution is responsible for 4.2 million deaths worldwide. Air pollution is one of the greatest environmental health risks. It is also

responsible for the degradation of natural resources, deterioration of infrastructure and the reduction of the cultivated area (Shahbaz, Tiwar, and Nasir 2013).

Mediterranean countries share a similar exposure to environmental risks and increasing tourism pressure. Pollution has become a growing problem in several regions of the Mediterranean basin (MedECC 2020; Ezzghari et al. 2023). These countries are responsible for around 6% of the world's CO_2 emissions. Furthermore, the Mediterranean is the world's leading tourism area in terms of international tourism, with more than 360 million international tourist arrivals, i.e. 27% of world tourism in 2017 (World Tourism Organisation 2019). Tourism in the Mediterranean has contributed to the creation of employment, infrastructure, the accumulation of foreign currencies, and economic growth. However, tourism activities have an impact on the environment and greenhouse gas emissions (Programme des Nations Unies pour l'Environnement 2005). Furthermore, since the 'Barcelona Process,' which was launched in 1995, the Mediterranean countries have implemented a process of gradual dismantling of their customs tariffs in order to increase trade between the EU and the Mediterranean countries.

Thus, trade openness facilitates the transfer and adoption of cleaner technologies and allows late industrializing countries to make technological leaps (Hettige, Lucas and Wheeler 1992; Porter 1999). Moreover, the Mediterranean region is marked by the attractiveness of foreign direct investment (FDI). Governments have undertaken far-reaching reforms to create more favorable investment climates. Ambitious legislative and institutional reforms have been undertaken by most Mediterranean countries in order to attract investment with better quality.

The increase in tourist flows, trade and FDI have an impact on energy demand and the environment. The Mediterranean region represents 9% of global energy demand. Total energy consumption in this region is about 1000 million tons of coal equivalent (tep) in 2007 and is expected to increase to 1400 million (tep) in 2030. As for renewable energies, it should represent 11% of global demand in 2030 (Keramane 2010).

Thus, the Mediterranean region remains particularly vulnerable to climate change and likely to be increasingly exposed to extreme climatic events. Is should be noted, all Mediterranean ecosystems (terrestrial, coastal and marine) are being impacted by climate change (Balzan et al. 2020; Hassoun et al. 2021). Moreover, Mediterranean countries have made significant mitigation commitments under the Paris Climate Agreement (MEDENER 2018).

The purpose of this study is to investigate the relationships between CO_2 emissions, trade openness, FDI, renewable energy, tourist arrivals, and economic growth. Our objective is to make two contributions to the existing body of literature: the first is to assess these relationships in Mediterranean countries for the period 1995–2018. The second is to use several econometric techniques that take into consideration both cross-sectional dependence and heterogeneity such as cross-sectional augmented IPS (CIPS) unit root tests and cross-sectional augmented Dickey-Fuller (CADF) tests and Westerlund cointegration tests, fully modified ordinary least squares (FMOLS), dynamic ordinary least squares (DOLS), dynamic seemingly unrelated regression (DSUR) estimators and Dumitrescu-Hurlin causality analysis. Thus, the results of this study provide a better understanding of the dynamic relationships between tourism, FDI, renewable energy, international trade, economic growth, and environmental quality in order to better guide policy makers in the countries around the Mediterranean.

The structure of this study is as follows: a thorough literature review is presented in the second section, data and estimation techniques are introduced in the third section, empirical results and discussion are reported in the fourth section, and the paper concludes with policy implications in the final section.

LITERATURE REVIEW

Tourism and CO_2 Emissions

The study of the relationship between tourism and the environment is expressed in terms of constraints arising from the effects either on tourism development due to the environment or on environmental degradation due to tourism growth. Thus, the negative environmental impacts resulting from tourism are related to the construction of general infrastructure such as airports, roads and tourist facilities and to the consumption of additional energy. These impacts can lead to destruction of the environmental resources on which tourism depends.

Moreover, the environment is an important factor in tourists' choices and therefore, in the development of a tourist destination (Galvani 1996).

Several studies have sought to assess the empirical influence of economic expansion and tourism development on CO_2 emissions. A panel of 15 Mediterranean nations was examined by Balli et al. (2018) over the years 1995–2014. The findings indicate that tourism receipts increase CO_2 emissions. With the exception of Egypt, Morocco, Italy, Spain, and Turkey, the data also suggest that the tourism-led growth hypothesis (TLGH) does not hold true for the majority of the study countries. In a 2014 study, Leon et al. examined the link between tourism and CO_2 emissions in both less developed and developed countries from 1998 to 2006. The results demonstrate that tourism contributes to CO_2 emissions in both types of countries.

The relationship between tourism, economic growth, energy consumption, and CO_2 emissions in Turkey was investigated by Eyuboglu and Uzar (2019) from 1960 to 2014. The authors concluded that tourism, growth and energy consumption have a positive effect on CO_2 emissions. They also found bidirectional causality between tourism and CO_2 emissions. In a sample of 18 developing economies and 26 developed economies, Paramati, Alam, and Chen (2017) examined the impact of tourism on economic development and CO_2 emissions for the period between 1995 and 2012. They concluded that tourism development has a positive impact on economic growth and CO_2 emissions. Wang and Wang (2018) investigated the effect of tourism on CO_2 emissions in OECD nations between 1995 and 2014. The findings indicate that there is a feedback relationship between CO_2 emissions and tourism development. Ozcan, Bekun, and Nazlioglu (2021) assessed the effects of increasing tourism on environmental quality for 16 Mediterranean nations between 1995 and 2014. In the nations with more competitive tourism industries, the results show a substantial causal association between tourism and CO_2 emissions; however, in other nations, the relationship is not supported.

Trade and CO_2 Emissions

In the framework of a study on 40 European nations, Jamel and Matsouf (2017) found a causal association that operates in both directions between trade liberalization and CO_2 emissions. In a similar vein, Işik, Kasımatı, and Ongan (2017) investigated the dynamic relationships between international trade and Greece's CO_2 emissions from 1970 to 2014. They came to the conclusion that Greece's CO_2 emissions increased as a result of trade liberalization. Jayanthakumaran, Verma, and Liu (2012) used the autoregressive distributed lag (ARDL) methodology to examine the long- and short-run relationships between trade and CO_2 emissions in a comparative study between India and China. Regarding the effect of trade intensity on CO_2 emissions, the empirical results were inconclusive and not significant in terms of trade intensity's impact on CO_2 emissions.

Additionally, Shahbaz et al. (2013) studied the impact of trade openness on CO_2 emissions in Indonesia. The results show that trade openness is negatively related to CO_2 emissions. They concluded that international trade provides developing economies with access to efficient technologies and techniques that emit less CO_2. The case of Italy was investigated by Bento and Moutinho (2016), who found that the impact of international trade is not significant in the short term but has a positive effect in the long term on CO_2 emissions, reaching a point where it affects pollution. Akin (2014) examined 85 nations between 1990 and 2011 in order to examine the effect of trade openness on CO_2 emissions. According to the empirical findings, trade openness has the potential to lower CO_2 emissions. Ohlan (2015) used ARDL modeling to investigate the relationship between global trade and CO_2 emissions in India from 1970 to 2013, finding that both the short and long-term effects are not noteworthy. Zhang, Liu, and Bae (2017) looked at the EKC hypothesis and how trade openness affected CO_2 emissions in industrialized nations between 1971 and 2013. The findings support the EKC hypothesis and show that trade has a negative impact on CO_2 emissions.

Using the pooled mean group-autoregressive Distributed Lag (PMG-ARDL) approach, Essandoh, Islam, and Kakinaka (2020) examined the effect of trade on CO_2 emissions in 52 nations between 1991 and 2014. They demonstrated that while the effect of international openness on CO_2 emissions is negligible for developing nations, it has a negative effect on industrialized nations.

FDI and CO_2 Emissions

In the context of India, Acharyya (2009) examined the effect of FDI on CO_2 emissions between 1980 and 2003. The empirical findings demonstrated a positive effect of FDI on CO_2 emissions. Gökmenoğlu and Taspinar (2015) examined the effect of FDI on carbon emissions as well as the EKC hypothesis, in Turkey. The findings indicate that FDI has a long-term positive effect on Turkey's CO_2 emissions. The authors also discovered a bidirectional relationship between FDI and carbon emissions.

For a sample of 18 Latin American nations, Blanco, Gonzalez, and Ruiz (2013) investigated the relationship between FDI and CO_2 emissions for the years 1980–2007. The findings suggest that higher CO_2 emissions may be associated with foreign direct investment in highly polluting industries. Baksh et al. (2017) studied how environmental pollution in Pakistan was affected by FDI between 1980 and 2014. The results of the investigation showed that FDI had a significant effect on increasing CO_2 emissions. Using both linear and nonlinear ARDL models, Haug and Ucal (2019) analyzed the effect of FDI on CO_2 emissions in Turkey. The findings suggest that there is no significant relationship between FDI and carbon emissions.

Demena and Afesorgbor (2019) used a meta-analysis of 65 primary papers to investigate the impact of FDI on the environment. The findings demonstrated that FDI significantly lowers emissions in the environment. In the case of the BRICS, Rafique et al. (2020) investigated the link between FDI and carbon emissions. The authors discovered that FDI had a detrimental impact on CO_2 emissions using the Augmented Mean Group (AMG) estimate. Moreover, causality tests show a unidirectional causal link from FDI to carbon emissions.

Renewable Energy and CO_2 Emissions

Dong, Sun, and Hochman (2017) examined a panel of data from 128 countries covering the period 1990–2014 to study the relationship between CO_2 emissions and renewable energy consumption. The empirical findings demonstrate that, for each of the six research zones, a rise in the intensity of renewable energy is accompanied by a fall in CO_2 emissions. Similarly, Waheed et al. (2017) used ARDL modeling to examine the impact of renewable energy consumption on carbon dioxide (CO_2) emissions in Pakistan between 1990 and 2014. They found that using more renewable energy can lower CO_2 emissions over the long term.

Saïdi and Omri (2020) assessed the effects of nuclear and renewable energy consumption on CO_2 emissions in OECD countries. The findings of various estimates demonstrate that using nuclear and renewable energy lowers carbon emissions. Conversely, Ben Jebli and

Ben Youssef (2017) examined the dynamic causal relationships between the consumption of renewable energy and carbon dioxide emissions in North African countries from 1980 to 2011. Granger causality test results show a unidirectional relationship between CO_2 emissions and renewable energy sources. Furthermore, the parameter estimates indicate that a long-term increase in the use of renewable energy sources is associated with a rise in CO_2 emissions. In contrast to earlier research, Acheampong, Dzator, and Savage (2021) investigated the relationship between renewable energy and carbon emissions in African countries. The findings demonstrate that there is no connection between renewable energy sources and carbon emissions.

Tourism, Trade, FDI, RE and CO_2 Emission

Using the generalized method of moments (GMM) approach, Balogh and Jambor (2017) examined the factors influencing CO_2 emissions in a panel of 168 countries. The outcomes attest to the beneficial contribution of renewable energy generation to the decrease in CO_2 emissions. Estimates have shown that the expansion of tourism and international trade can hasten environmental degradation by raising atmospheric CO_2 emissions.

Using the weighted-average least squares (WALS) approach, Aller, Ductor, and Grechyna (2021) investigated the factors influencing CO_2 emissions for a panel of 92 countries. The findings indicate that income and FDI increase environmental degradation, while tourist arrivals have a negative impact on the environment. Leitão and Lorente (2020) employed three estimation methods – FMOLS, DOLS and GMM-System – to analyze the empirical relationship between tourist arrivals, trade openness, renewable energy, economic growth, and CO_2 emissions in European Union countries for the period 1995–2014. Estimates indicate that while trade openness, the amount of renewable energy consumption, and international tourist arrivals all have a negative impact on CO_2 emissions, economic growth has a positive effect on these emissions. Similarly, Khan and Ahmad (2021) evaluated the effects of tourism, international trade, FDI, and renewable energy consumption on CO_2 emissions in a selection of developed European countries and developing Asia-Pacific countries between 2000 and 2020. According to estimates, trade openness and renewable energy consumption have a negative impact on carbon emissions in industrialized countries, whereas tourism and FDI have a beneficial impact.

TABLE 1 A Survey of Existing Literature

Author(s)	Country/region	Period	Methodology	Conclusion
Ben Jebli and Hadhri (2018)	United States, China, Turkey, Mexico, Germany, Italy, Spain, France, Russian Federation and United Kingdom	1995–2013	VECM and Granger causality test approach	CO_2 → tourism; GDP ↔ tourism; energy ↔ tourism
Dogan and Aslan (2017)	25 EU	1995–2011	Panel Granger causality	Tourism → CO_2; GDP → tourism
Zhang and Zhang (2021)	30 Chinese provinces	2000–2017	Granger causality tests	CO_2 ↔ tourism; GDP ↔ tourism
Ravinthirakumaran and Ravinthirakumaran (2023)	APEC region	1995–2017	Panel Granger causality	Tourism → CO_2
Katircioglu, Feridun, and Kilinc (2014)	Cyprus	1970–2009	Granger causality tests	Tourism → CO_2; Energy → tourism
Ben Jebli, Ben Youssef, and Apergis (2019)	22 American countries	1995–2010	Panel Granger causality	CO_2 ↔ tourism; Tourism ↔ trade; Renewable energy ↔ tourism; FDI ↔ tourism
Akadiri et al. (2020)	16 small island developing countries	1995–2014	Granger causality tests	CO_2 ↔ tourism
Balli et al. (2018)	15 Mediterranean countries	1995–2014	Granger causality tests	Tourism → GDP (Spain, Italy, and Egypt); Tourism ↔ GDP (Turkey and Morocco); Tourism → CO_2
Selvanathan, Jayasinghe, and Selvanathan (2021)	South Asia	1990–2014	Heterogeneous panel causality test	GDP → tourism; tourism → CO_2; tourism → energy; capital → tourism

Continued on the next page

In summary, the results are generally mixed and vary according to empirical specifications, data used, econometric methods and countries studied. This paper examines the relationships between tourism, international trade, FDI, renewable energy consumption, economic growth and CO_2 emissions for Mediterranean countries. The impact

TABLE 1 *Continued from the previous page*

Author(s)	Country/region	Period	Methodology	Conclusion
Nosheen, Iqbal, and Khan (2021)	Asian economies	1995–2017	Bootstrap panel co-integration test	Tourism → CO_2
Paramati, Alam, and Lau (2018)	28 EU member states	1990–2013	Panel Granger causality	Tourism investment ↔ tourism revenue; tourism investment → CO_2
Koçak, Ulucak, and Ulucak (2020)	10 countries	1995–2014	Heterogeneous panel causality test	Tourism ↔ CO_2;
El Menyari (2021)	Morocco, Algeria, Tunisia, and Egypt	1980–2014	Heterogeneous panel causality test	Tourism → CO_2; GDP ↔ tourism; electricity consumption → tourism

NOTES → unidirectional causality, ↔ bidirectional causality.

of these variables on CO_2 emissions and the study of causal links are rarely analyzed in the Mediterranean context. Therefore, this study contributes both to the existing literature and to the development of relevant policies for sustainable tourism, FDI, and international trade in Mediterranean countries (table 1).

METHODOLOGY FRAMEWORK

Model and Data

The EKC hypothesis is the theoretical framework that serves to investigate how tourism, trade, FDI and renewable energy sources affect environmental quality. The groundbreaking study by Grossman and Krueger (1991), as well as more recent research by Muhammad et al. (2020), Dogru et al. (2020), Leitão and Lorente (2020), and Khan and Ahmad (2021), inspired the development of the EKC's functional shape, which analyzes factors that influence CO_2 emissions, such as the growth of tourism, FDI, trade openness, and renewable energy, integrated into the traditional EKC model. Therefore, this study aims to examine the following hypotheses:

- H1 *There is an inverse U relationship between growth and carbon dioxide emissions.*
- H2 *There is a negative relationship between tourism development and CO_2 emissions.*
- H3 *There is a negative relationship between FDIs and CO_2 emissions.*

H4 *There is a negative link between trade openness and CO_2 emissions.*

H5 *Renewable energy is expected to reduce CO_2 emissions.*

Thus, the model specification is presented as follows:

$$CO_{2it} = \varphi_0 + \varphi_1 GDP_{it} + \varphi_2 GDP_{it}^2 + \varphi_3 TA_{it} + \varphi_4 RE_{it} + \varphi_5 Trade_{it} + \varphi_6 FDI_{it} + \varepsilon_{it}. \quad (1)$$

In this equation, the variables are defined as follows: CO_2 – carbon dioxide emissions measured in metric tons per capita; GDP – real GDP per capita (represented in USD), as a measure of economic performance, GDP^2 real GDP per capita squared to examine the EKC hypothesis; TA – tourist arrivals, representing the number of tourists who travel to a country other than where they habitually reside; RE – renewable energy consumption, which represents total renewable electricity consumption, measured in billions of kilowatt hours; *Trade* – trade openness ratio, measured by exports plus imports of goods and services as a percentage of GDP; FDI – foreign direct investment, net inflows as a percentage of GDP. $\varepsilon_i t$ is the standard error term, φ_1,φ_2,φ_3,φ_4,φ_5 and φ_6 are the model parameters. The country and time dimensions are denoted by the sub-indices i and t, respectively.

Within the framework of panel data, this work examines the effects of FDI, tourism, income, and renewable energy consumption on environmental quality in the Mediterranean region, specifically in Morocco, Portugal, Greece, Spain, Albania, Croatia, Israel, Cyprus, Egypt, Algeria, Italy, Tunisia, Turkey, Lebanon, Malta, Slovenia, and France between 1995 and 2018.

All data were obtained from the World Development Indicators (WDI) database, except for renewable energy consumption, which was obtained from the US Energy Information Administration database. Natural logarithms are used to express all variables.

Methodological Approach

We broke down the econometric estimation process into five parts to accomplish the study's goals. The first step investigates the cross-sectional independence between the variables using the tests created by Breusch and Pagan (1980) and Pesaran (2004). The second step examines the degrees of integration of the variables with the CIPS and CADF unit root tests of Pesaran (2007), which take into account the serial dependence and the heterogeneity of slope coefficients in the cross-section dimension. The third step analyzes the long-term relationship structure between the variables using the Westerlund (2007) cointegration test. After determining the existence of a cointegrating relationship, in the fourth step, we use the FMOLS, DSUR and DOLS estimators to study the long-term effect of the independent variables on carbon emissions. Finally, we apply the panel causality test, introduced by Dumitrescu and Hurlin (2012), in the final stage.[1]

Cross-Sectional Independence Tests

Because of the direct and indirect economic ties that exist between the countries in the model, a shock that affects one country might also affect other countries, which makes cross-sectional dependence a significant issue in panel data models. As a result, if this dependence is ignored, estimates may become skewed (O'Connell 1998).

We use the Lagrange multiplier (LM) test, and the cross-section dependence (CSD) test to validate the cross-sectional dependence because the temporal dimension (T) is larger than the sample size (N).

Panel Unit Root Tests

We use the CADF and CIPS tests, which are the second-generation unit root tests developed by Pesaran (2007), as a second stage of the empirical investigation. These tests account for the heterogeneity and cross-sectional dependence of the parameters.

Based on the Augmented Dickey Fuller (ADF) approach, the CADF test can be expressed as follows:

$$\Delta y_{it} = a_i + b_i y_{i,t-1} + c_i y_{t-1} + \sum_{j=0}^{p} d_{ij} \Delta y_{t-j} + \sum_{j=1}^{p} \varphi_{ij} \Delta y_{t-j} + e_{it}, \quad (2)$$

where y_t is the average at time T of all the N countries. After using the CADF test, the CIPS test can be obtained as follows:

$$\text{CIPS} = N^{-1} \sum_{i=1}^{N} t_i(N,T), \quad (3)$$

where $t_i(N,T)$ is the t-statistic in the CADF regression (Equation 2).

[1] The econometric analysis was carried out using STATA software.

Cointegration Test Panel

Next, we apply Westerlund's (2007) panel cointegration test, which allows us to account for the variability of cointegrating vectors and cross-sectional independence, to investigate the likelihood of a cointegration

relationship between the variables under study.

Long-Run Estimates: FMOLS, DOLS, DSUR

We employ three estimation techniques to evaluate the long-term association between the variables after examining stationarity and cointegration. To prevent biased estimates, we use the Dynamic Seemingly Unrelated Regression (DSUR) developed by Mark et al. (2005) as well as the cointegration regressions created by Pedroni (2001), which include fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) estimators. The first two methods make it possible to reinforce the robustness of panel data analysis results, by considering the problems of endogeneity among the repressors and the autocorrelation of errors, while the third method is robust in cases of CSD and heterogeneity issues, in addition to its ability to produce more robust estimates when the time dimension is significantly larger than the sample size (*N*) (Mark et al. 2005).

Dumitrescu-Hurlin Panel Causality Analysis

The final phase is to use Dumitrescu and Hurlin's (2012) causality test, which is regarded as an extension of the traditional Granger causality approximation, to investigate the causal interactions between the variables in our model. This test accounts for cross-sectional dependence and the presence of diverse panel data.

EMPIRICAL RESULTS AND ANALYSIS

Regarding the descriptive statistics presented in table 2, we note that, with the exception of the variable of CO_2 emissions per capita, the others series has significant dispersion around its own average. In fact, average CO_2 emissions per person show an average of 4.910533 and a standard deviation of 2.368148 in the countries studied, compared to GDP (SD = 11363.87), renewable energy consumption (SD = 29.54122), tourism arrivals (SD = 29666341), trade openness (SD = 52.10496) and foreign direct investment (SD = 1.54E+10). Also, the measure of skewness indicates a left-tailed distribution of the median, and therefore the distribution is right-skewed. Moreover, the measurement of kurtosis

TABLE 2 Descriptive Statistics

	CO2	GDP	RE	TA	Trade	FDI
Mean	4.910	15866.610	19.166	21536170	82.885	9.01E+9
Median	4.998	16093.380	4.328	6494500	66.318	2.23E+9
Maximum	9.615	38276.470	122.737	1.24E+8	322.676	8.51E+10
Minimum	0.470	1464.379	0.000	119000	30.246	−9.50E+9
Std. dev.	2.368	11363.870	29.541	29666341	52.104	1.54E+10
Skewness	0.040	0.294	1.7428	1.484	2.700	2.586
Kurtosis	1.876	1.691	4.991	3.930	10.577	10.011
Jarque-Bera	21.587	35.008	273.962	164.652	1472.008	1290.797
Probability	0.000021	0.000000	0.000000	0.000000	0.000000	0.000000

TABLE 3 Correlation Matrix

Variables	CO2	GDP	RE	TA	Trade	FDI
CO_2	1.0000					
	–					
GDP	0.9125	1.0000				
	0.0000	–				
RE	0.2270	0.2956	1.0000			
	0.0000	0.0000	–			
TA	0.2888	0.4099	0.7588	1.0000		
	0.0000	0.0000	0.0000	–		
Trade	0.1798	0.1792	-0.7229	-0.3871	1.000	
	0.0003	0.0003	0.0000	0.0000	–	
FDI	0.1452	0.2437	0.3091	0.3301	−0.1031	1.0000
	0.0033	0.0000	0.0000	0.0000	0.0374	–

shows mixed results; the distribution of CO_2 emissions and income per capita are platykurtic (kurtosis values are lower than the normal value) while the distribution of the other variables is leptokurtotic. Similarly, the Jarque-Bera test offers compelling evidence against the normality of the variables under investigation.

Table 3 examines the correlation matrix between the variables. The results show that the variables of GDP, TA, RE, trade openness and FDI are positively correlated with CO_2 emissions.

The variance inflation factor (VIF) and tolerance for each independent variable were calculated and are shown in table 4 to assess multicollinearity. The outcomes of these tests indicate that there is no multicollinearity issue because the tolerance values are not less than 0.2 and the VIF values are less than 5. As a result, all independent variables can be taken into account in our econometric models.

TABLE 4 Test of Multicollinearity

Variable	GDP	TA	RE	Trade	FDI	Mean
VIF	1.46	2.59	2.30	1.56	1.14	1.81
Tolerance	0.686532	0.386748	0.434744	0.640655	0.874809	

TABLE 5 Pesaran-Yamagata's Homogeneity Test

Test	Delta (Δ)	Adjusted delta
Statistics	14.987	17.807
Probability	0.000	0.000

TABLE 6 Cross-Sectional Dependence Test

Variables	CO_2	GDP	RE	TA	Trade	FDI
Breusch-Pagan LM	1349.769***	2008.246***	1283.896***	1909.438***	1136.769***	434.9846***
Pesaran scaled LM	73.595***	113.521***	69.601***	107.530***	60.680***	18.128***
Pesaran CD	6.289***	41.871***	23.168***	40.0353***	23.982***	12.343***

NOTES *** Significance level: 1%.

Table 5 displays the results of the Pesaran and Yamagata (2008) homogeneity tests. These tests support the alternative hypothesis of heterogeneity over the null hypothesis of panel homogeneity. As a result, this analysis highlights the prevalence of heterogeneity and the necessity of using heterogeneous panel data methodologies.

The findings of the cross-sectional dependence test demonstrate that the probability values (p-value) are significantly below the 1% threshold, indicating that the null hypothesis of independence is rejected at that point (table 6). As a result, a shock that originates in one Mediterranean nation may spread to neighboring nations.

We conducted unit root tests, specifically the CIPS and CADF, which account for cross-sectional dependency, since the earlier results show the presence of cross-sectional dependence and the heterogeneity of

TABLE 7 CADF and CIPS Panel Unit Root Test

Variables		CO_2	GDP	RE	TA	Trade	FDI
CADF	(a)	1.547	0.231	0.312	0.533	−0.216	−1.156
	(b)	−8.613***	−5.757***	−4.042***	−4.413***	−5.554***	−3.264***
CIPS	(a)	−0.975	−1.800	1.936	−1.699	−1.407	−0.557
	(b)	−4.710***	−3.409***	−6.440***	−3.887***	−3.675***	−2.876***

NOTES Row headings are as follows: (a) level, (b) first difference. *** Significance level: 1%.

TABLE 8 Panel Cointegration Test

Pedroni	Panel	V-test	−3.1723***
		Rho-test	2.8781***
		PP-test	−2.6152***
		ADF-test	−1.8160**
	Group	Rho-test	3.9198***
		PP-test	−3.7890***
		ADF-test	−2.5289***
Kao		ADF statistic	−3.2604***
Westerlund		Variance ratio	2.2913***

NOTES *** Significance level: 1%. ** Significance level: 5%.

the slopes. According to table 7's results, all of the variables have unit roots (non-stationary) at every level and are integrated of order one I(1); as a result, their linear combination needs to be a stationary process I(0). In order to investigate whether there is a long-term relationship between the variables, cointegration tests were carried out.

We examined cointegration between variables using the Pedroni, Westerlund, and Kao tests. We infer that the variables under study are cointegrated since table 8's results show that the tests are statistically significant. Thus, panel cointegration techniques were used to evaluate the long-term relationship between the variables. Table 9 reports the findings of the DSUR, FMOLS and DOLS.

Note that the methods we employed are more resilient and efficient than the OLS method (Mark et al. 2005; Ben Jebli, Ben Youssef, and Ozturk 2016; Adebayo et al. 2021; Ximei et al. 2024). These methods are the FMOLS, DOLS, and DSUR methods. As a result, the findings indicate that there is a positive relationship between real income and CO_2,

TABLE 9 Long-Run Estimation Results

Independent variables	Dependent Variable CO_2					
	FMOLS		DOLS		DSUR	
	(1)	(2)	(1)	(2)	(1)	(2)
GDP	6.0577***	0.0000	6.7017***	0.0001	5.1608***	0.0000
GDP^2	−0.3563***	0.0000	−0.3466***	0.0003	−0.2486***	0.0000
RE	−0.1062***	0.0000	−0.0895***	0.0000	−0.0500***	0.0000
TA	−0.0572***	0.0000	−0.0195***	0.6048	−0.0101	0.2320
Trade	−0.2413***	0.0000	−0.2656***	0.0080	−0.2299***	0.0000
FDI	−0.0024	0.9113	−0.0206***	0.0005	−0.0086***	0.0010

NOTES Column headings are as follows: (1) coefficient, (2) probability. *** Signific. level: 1%.

ranging from 5.16% to 6.7%. This suggests that rising per capita income in Mediterranean nations is associated with rising CO_2 emissions. Economic growth has a significant impact on CO_2 emissions.

Moreover, our findings support the existence of an inverted U-shape (coefficients $\beta_1 > 0$ and $\beta_2 < 0$) for the Mediterranean countries, validating the environmental Kuznets curve hypothesis. Our empirical findings are consistent with those of Dogan et al. (2020) and Grossman and Krueger (1991). Furthermore, the elasticity of carbon emissions, ranging from 0.05% to 0.10%, is strongly negative in relation to RE. This finding implies that improving environmental quality is a direct effect of increasing the use of renewable energy sources. Consequently, several researchers have demonstrated the role of renewable energy in reducing carbon emissions. Indeed, the deployment of green projects and green spending can make low-carbon technologies more commercially viable and accessible to the public (Muth 2023).

Similarly, there is statistical significance and a negative coefficient associated with tourist arrivals. Therefore, ceteris paribus, a 1% increase in tourism results in a decrease in carbon dioxide emissions per person of 0.01% to 0.05%. This finding suggests that the Mediterranean region's tourism industry may be a vital tool for reducing CO_2 emissions and promoting sustainable development.

Previous studies of Dogan and Aslan (2017), Bella (2018), Akadiri et al. (2020) and El Menyari (2021), also found the same impact on CO_2 emissions. However, these studies did not integrate other variables likely to influence CO_2 emissions and were conducted with a restricted sample of countries. In addition, trade has a negative and significant impact on CO_2 emissions. Indeed, a 1% increase in international trade, ceteris paribus, reduces carbon dioxide emissions per capita by 0.26%. This result is similar to those of several studies, such as Sinha and Shahbaz (2018), Chen, Wang, and Zhong (2019), and Leitão and Lorente (2020). However, this finding contrasts to that of Islam et al. (2021), who found that increasing GDP increases CO_2 emissions in Bangladesh.

Furthermore, there is a statistically significant negative relationship between FDI and CO_2 emissions. This outcome differs from the conclusions drawn by Rafique et al. (2020) and Wang et al. (2022). It does not, however, align with the conclusions of Salahodjaev and Isaeva (2022) on 20 post-Soviet republics or Khan et al. (2021) in the case of 69 BRI countries.

TABLE 10 Dumitrescu and Hurlin Test

HO	W-Statistics	Zbar-Statistics
GDP does not cause CO_2	4.04414	7.06239***
CO_2 does not cause GDP	3.17565	4.97116***
RE does not cause CO_2	2.41214	3.13273***
CO_2 does not cause RE	2.20326	2.62975***
TA does not cause CO_2	4.20837	7.45782***
CO_2 does not cause TA	2.34069	2.96069***
TRADE does not cause CO_2	2.15850	2.52199**
CO_2 does not cause TRADE	3.86295	6.62610***
FDI does not cause CO_2	3.25123	5.15316***
CO_2 does not cause FDI	3.90959	6.73840***
RE does not cause GDP	1.30396	0.46436
GDP does not cause RE	2.83185	4.14333***
TA does not cause GDP	2.41101	3.13001***
GDP does not cause TA	1.98098	2.09454**
TRADE does not cause GDP	3.48048	5.70516***
GDP does not cause TRADE	1.65274	1.30419
FDI does not cause GDP	1.83438	1.74154*
GDP does not cause FDI	3.51863	5.79702***
TA does not cause RE	2.89829	4.30332***
RE does not cause TA	2.13842	2.47363**
TRADE does not cause RE	2.76609	3.98499***
RE does not cause TRADE	2.93376	4.38873***
FDI does not cause RE	0.80283	−0.74231
RE does not cause FDI	1.16212	0.12283
TRADE does not cause TA	0.91278	−0.47755
TA does not cause TRADE	3.41431	5.54584***
FDI does not cause TA	0.87530	−0.56781
TA does not cause FDI	3.97261	6.89015***
FDI does not cause TRADE	3.06594	4.70700***
TRADE does not cause FDI	3.91527	6.75208***

NOTES *** Significance level: 1%. ** Significance level: 5%.* Significance level: 10%.

In order to determine the relationship between CO_2 emissions, RE, GDP, TA, Trade, and FDI for the sample nations, we additionally examine the Dumitrescu and Hurlin causality test. Table 10 displays the outcomes of the Dumitrescu and Hurlin causality test. We have compelling evidence that the other variables under study trade, FDI, RE, TA, and GDP are causally related to CO_2 emissions in both directions. This implies that coordinated implementation of policies related to the environment, renewable energy, tourism, and economy will be necessary.

Furthermore, there is a unidirectional causal relationship between real income and Trade as well as the RE. Lastly, there was no discernible causal link between FDI and RE (table 10 on p. 329).

CONCLUSION

This study analyzes the influence of renewable energy consumption, tourism, international trade and foreign direct investments on CO_2 emissions in the presence of the EKC model in the Mediterranean countries over the period 1995–2018, by using appropriate econometric methods such as panel estimation techniques with cross-sectional dependence.

The results of the unit root tests in the CADF and CIPS panel reveal that all the variables are not stationary in level and are integrated of order one. Westerlund's test (2007) indicates that the variables studied are cointegrated. Thus, the results of econometric estimates show that economic growth strongly influences carbon emissions. Moreover, our support the existence of an inverted U-shaped for the Mediterranean countries, which confirms the existence of the Environmental Kuznets Curve hypothesis. On the other hand, our results show that tourism, renewable energy consumption, trade openness, and FDI have a negative and statistically significant impact on CO_2 emissions. In addition, the results of Dumitrescu and Hurlin test show the existence of a bidirectional causality between CO_2 emissions and the other variables studied (GDP, RE, TA, Trade, FDI) and unidirectional causality ranging from RE and Trade to real income, while no causal relationship was observed between RE and FDI.

The empirical analysis leads to several implications. First, to support sustainable development and green growth, the Mediterranean region countries must continue to advance technological innovation. Then, the negative impact of energy consumption on carbon emissions suggests that actions must be taken to reduce the financial cost of the transition to renewable energies through fiscal and regulatory measures. Finally, it would be appropriate to encourage the liberalization of trade in the field of renewable energies and to utilize these energies to support tourism and foreign investments at a sustainable level that can be favorable to economic growth and environmental quality.

Furthermore, our results reveal that tourism can play a key role in promoting international trade, FDI, RE and reducing CO_2 emissions in the Mediterranean region. Therefore, public authorities in Mediterranean countries must ensure coordination and consultation between stakeholders operating in the tourism sector to develop the infrastructure and host a significant number of business events. Similarly, sustainable tourism development and renewable energy transition require awareness-raising and support actions for tourism stakeholders by public authorities to encourage tourism that aligns with economic development, environmental preservation, and resource management. Our study has some limitations. First of all, our study only samples countries around the Mediterranean, so we suggest that other researchers extend our work to other regions of the world. Second, the current study can be expanded using recent econometric tests that better capture crises and structural changes.

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