sustainability

MDPI

Article

Renewable Energy and Carbon Emissions: New Empirical Evidence from the Union for the Mediterranean

Burak Erkut

Faculty of Economics, Administrative and Social Sciences, Bahçeşehir Cyprus University, Nicosia 99200, Turkey; burak.erkut@baucyprus.edu.tr

Abstract: This approach focuses on the renewable energy-carbon emission nexus by delivering new empirical evidence from 37 members of the Union for the Mediterranean. The approach makes use of panel data for the period 2002–2018 and uses panel data econometrical approaches, which are panel random effects regression, feasible generalized least squares regression, and the difference-generalized method of moments estimation, to understand how agricultural activity, economic growth, and renewable energy use impact carbon emissions. The results indicate that economic growth increases carbon emissions, whereas renewable energy use decreases them. In addition, separate analyses for EU and non-EU members indicate that agricultural activity has a significant negative effect only for the non-EU countries, which is further discussed with some relevant empirical evidence. The approach utilizes three fields of policy action. Firstly, economic growth comes to the Union countries with a cost-carbon emissions. Policymaking needs to include strategies to turn growth into sustainable growth. Secondly, the magnitude of the impact of economic growth on carbon emissions is greater than the magnitude of the impact of renewable energy. Research and development efforts need to improve this situation. Thirdly, the use of appropriate tools and technologies can decrease the carbon footprint of agricultural activity.

Keywords: renewable energy; carbon emissions; economic growth; agricultural activity

check for updates

Citation: Erkut, B. Renewable Energy and Carbon Emissions: New Empirical Evidence from the Union for the Mediterranean. *Sustainability* **2022**, *14*, 6921. https://doi.org/10.3390/su14116921

Academic Editor: Fabio Carlucci

Received: 4 May 2022
Accepted: 6 June 2022
Published: 6 June 2022

1. Introduction

1.1. Setting the Scene

In recent years, the Mediterranean region has received global attention when it comes to energy issues. On the one hand, the discovery of oil and natural gas reserves in the Eastern Mediterranean by Türkiye created dynamism regarding regional collaborations but also confrontations [1]. On the other hand, the Mediterranean region is known for its recent adoption of policies related to clean energy and sustainable economic development policies as a response to the ongoing challenges of global warming [2]. However, the current state of environmental degradation in the Mediterranean region is alarming, and despite many national and supranational attempts to preserve environmental quality, the current state of action plans is far from being complete.

On the one hand, the literature delivers empirical evidence identifying a positive relationship between economic growth and carbon emissions [3], indicating that economic growth comes with a cost for the environment. Despite the famous Environmental Kuznets Curve hypothesis, which indicates that this reality only reaches a certain threshold, and not beyond this, recent empirical evidence indicates that when a country switches to environmentally friendly technologies, this does not immediately reflect itself in economic growth perspectives, but it rather takes time [4]. Therefore, the use of renewable energies—despite their role in emission reduction—seems to be rather a long-run approach that does not show benefits in the short run. Furthermore, recent empirical evidence highlights a negative relation between agricultural land use and renewable energy use [2], which brings an additional trade-off for policymaking on whether to focus on agricultural production or use the land for renewable energy production. In this sense, the agriculture–growth–renewable energy–carbon emission relation is not only complex, but also far from complete in the literature.

Following these concerns, the present approach focuses on the carbon emission–renewable energy nexus to understand the link between carbon emissions, agricultural activity, the gross domestic product per capita (GDP)—capturing economic growth—and renewable energy use. To analyze this, the approach utilizes data from the World Bank Development Indicators to focus on 37 member countries of the Union for the Mediterranean and a period of 2002–2018. Since the data utilized are panel data, panel data econometrics techniques are used to analyze the data to answer the question of how renewable energy use, economic growth, and agricultural activity impact carbon dioxide (carbon) emissions.

The rest of the contribution is structured as follows. In what follows, a literature review is provided with the target of identifying state-of-the-art findings regarding the carbon emission–renewable energy nexus. Section 2 presents the materials and methods of the study, describing the data and the procedures of data analysis being utilized. Section 3 presents the results of the panel data analysis. Section 4 discusses the results by relating them to the state-of-the-art findings from the literature. A conclusion is provided in Section 5 with policy implications and limitations, the latter providing avenues for further research.

1.2. Literature Review

Economic development, despite its environmental degradation impact, is necessary to guarantee environmental sustainability [4]. That being said, the growth–energy nexus has been associated with a very important and negative side effect—pollutants in the atmosphere—which has undergone a sharp increase since industrialization and emerged as a hot topic of climate change in the recent scholarly and political debates [5]. On the one hand, economic growth was accompanied by the intensive use of energy from fossil fuels, and, on the other hand, this has triggered the release of pollutants to the atmosphere and, consequently, contributed vastly to climate change. Even though climate change has become a serious problem across the world, one of the most alarming regions is the Mediterranean region, with its nearly 500 million population. Energy demand in Southern Mediterranean countries will increase by 62% in 2040, but the fact that the average temperature of 1.5 degrees Celsius determined in the Paris Agreement is already exceeded in the Mediterranean region raises concerns [6].

A recent report by the Union for the Mediterranean indicates that, by the end of the 21st century, the average warming of the Mediterranean region will be 20% above the global average [7]. In addition, the same report indicates that this region has low water resources, which are unevenly distributed; the region has a particularly vulnerable agricultural sector because of a combination of low water resources, intensified carbon emissions, and the expectation of low crop yields in the near future, and the region's energy use is largely based on fossil fuels. In combination, this gives a pessimistic picture of the region's current environmental situation and calls for action towards a twofold strategy of greenhouse gas emission mitigation and adaptation to the impacts of climate change.

As a response to this twofold strategy, several contributions have emerged in the literature to understand the current situation of the Mediterranean region vis-à-vis the growth–energy nexus. Table 1 provides an overview of these scientific contributions. To start with, [8] focuses on innovations in the transportation sector in a number of Mediterranean countries to understand how they impact carbon emissions. The authors find that despite the role of innovations to reduce carbon emissions, they only have a positive impact in developing (and not in developed) Mediterranean countries. The contribution by [3] focuses on the role of tourist arrivals and tourism receipts with respect to carbon emissions. The baseline findings indicate that these two effects reduce carbon emissions, but once the authors take per capita income into account, the effect changes. In this case, tourist arrivals lead to an increase in carbon emissions up to a certain point; however, beyond this point, they decrease. With respect to the role of tourism receipts, the authors cannot find straightforward evidence. Moreover, [9] investigate what drives carbon emissions vis-à-vis growth and income inequality by focusing on a group of Mediterranean countries. The results of the empirical analysis indicate that income inequality leads to greater environmental degradation in the long run. In addition, the authors also find a positive relation between income inequality and carbon emissions.

On the other hand, the contribution by [5] specifies the energy–growth nexus in the Mediterranean region by distinguishing between renewable and non-renewable energy use. The most important implication of the empirical study is that the Mediterranean region's carbon emissions are stimulated by non-renewable energy use and economic growth. However, to counterbalance this issue, renewable energy use can be responsible for decreasing carbon emissions in this region. The implication is that renewable energy use should be extended to mitigate the impact caused by non-renewable energy use. Similarly, the contribution by [10] investigates the role of renewable and non-renewable energy use in the Mediterranean, and how they are impacting carbon emissions. The author identifies a bidirectional causality between growth and energy use in the short run, and a causality relation between renewable energy use and economic growth in the long run. Furthermore, energy use is the most important explanatory variable that can explain growth. The approach concludes by suggesting improving renewable energy use in the Mediterranean region, not only for limiting carbon emissions but also for enhancing the sustainable growth perspective.

The contribution by [11] focuses on new entrant EU members, which are also part of the Union for the Mediterranean, and questions the role of the agricultural sector in carbon emissions. The authors find that the Environmental Kuznets Curve hypothesis is confirmed for the agricultural sector, and they advise us to focus on new agricultural methods that can reduce carbon emissions. However, a questionable issue in this setup is whether methods to reduce carbon emissions can provide the same level and quality of performance as conventional methods. Similarly, the contribution by [2] investigates agricultural land use, tourism, and renewable energy use in different Mediterranean countries. The authors identify a negative relation between agricultural land usage and renewable energy use. The authors indicate that agricultural activities contribute to a long-term negative relation with renewable energy use, since excessive agricultural activities lead to depletion but also to the ineffective utilization of renewable energy practices.

Furthermore, the contribution by [12] investigates coastline Mediterranean countries by analyzing their housing construction policies, tourism activities, and carbon emissions. The authors highlight that these variables contribute positively to renewable energy growth, and suggest that stakeholders of the energy, environment, and tourism sectors should work together to balance the energy–growth nexus of their countries. In particular, the energy use–housing construction relation is considered to have a proactive policy perspective, calling for the avoidance of a mismatch that could endanger the energy and sustainability targets. On the other hand, [13] identify that renewable energy use and urbanization decrease carbon emissions, whereas economic growth and non-renewable energy use increase carbon emissions. One issue that the authors identify is that although the positive impact of renewable energy on carbon emissions and the negative impact of non-renewable energy on carbon emissions are known impacts, their magnitudes are far from being equal—the magnitude of the effect of renewable energy use on carbon emissions is identified to be only marginal, and, as such, a more focused policy orientation is suggested by the authors to increase the magnitude of this impact. Regarding the causality of energy use and sustainable development, [14] identify, for 14 countries of the Union for the Mediterranean Union, that there is no causality between these two concepts, whereas a bidirectional causality between economic growth and energy use is identified. In other words, energy use contributes to economic growth, but not necessarily to sustainable economic growth. The key challenge is to understand the current dynamics of environmental and economic sustainability, notice the deficiencies, and formulate policies towards turning development into sustainable development, as discussed by [14].

Table 1. Review of the scientific literature.

Contribution	Country and Period	Main Variables	Methodology	Results
[8]	Albania, Algeria, Bosnia and Herzegovina, Croatia, Egypt, Morocco, Tunisia, Türkiye (1997–2017), Cyprus—South, France, Greece, Israel, Italy, and Spain (2003–2017).	Carbon emissions, patent applications, trademark applications, GDP per capita	Pooled mean group, dynamic fixed effects	Innovation has a positive impact on carbon emissions only for developing Mediterranean countries.
[3]	Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus—South, Egypt, France, Greece, Israel, Italy, Lebanon, Morocco, Spain, Tunisia, and Türkiye (2001–2017).	Carbon emissions, number of international tourist arrivals, tourism receipts, GDP per capita	Panel threshold	Tourist arrivals increase carbon emissions up to a certain point. Tourism receipts reduce carbon emissions. GDP per capita increases carbon emissions.
[9]	Algeria, Cyprus-South, Egypt, France, Greece, Italy, Lebanon, Morocco, Spain, Tunisia, and Türkiye (1980–2012).	Carbon emissions, GDP per capita, Gini index	Common Correlated Effects Mean Group and Pooled Mean Group Estimations	Income inequality has a negative relation with carbon emissions in the long run, a positive relation with carbon emissions in the short run.
[5]	Algeria, Egypt, France, Greece, Italy, Morocco, Spain, Tunisia, and Türkiye (1980–2014).	Carbon emissions, renewable energy use, non-renewable energy use, GDP per capita	Common Correlated Effects Mean Group and Pooled Mean Group Estimations	Renewable energy use is a determinant of growth, growth is a determinant of renewable energy use.
[11]	France, Portugal, and Spain (1992–2014).	Carbon emissions, net value added of agriculture per capita	Autoregressive Distributive Lag	Environmental Kuznets Curve Hypothesis is validated.
[10]	Algeria, Cyprus, Egypt, Spain, France, Greece, Italy, Israel, Lebanon, Malta, Morocco, Syria, Tunisia, and Türkiye (1980–2011).	Carbon emissions, renewable energy use, non-renewable energy use, real GDP	Generalized Method of Moments, Vector Error Correction Model	Renewable and non-renewable energy use have positive impact on economic growth. Degradation of the environment accelerates growth, growth accelerates environmental degradation.
[12]	Spain, France, Slovenia, Greece, Turkey, Lebanon, and Israel (1999–2014).	Carbon emissions, housing construction, tourism, renewable energy growth	Autoregressive Distributed Lag, Pooled Mean Group Estimations	Carbon emissions increase renewable energy growth.
[2]	Albania, Algeria, Bosnia and Herzegovina, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Malta, Morocco, Slovenia, Spain, Tunisia, and Türkiye (1995–2014).	International tourism arrivals, agricultural land use, renewable energy use	Autoregressive Distributive Lag	Negative relation between agricultural land use and renewable energy consumption.

Table 1. *Cont.*

Contribution	Country and Period	Main Variables	Methodology	Results
[13]	Albania, Bosnia and Herzegovina, Algeria, Morocco, Croatia, Lebanon, Egypt, Tunisia, and Türkiye (1995–2016).	Gross domestic product per capita, urbanization, and renewable and non-renewable energy consumption	Fully Modified Ordinary Least Squares	Economic growth and nonrenewable energy use increase carbon emissions; urbanization and renewable energy decrease carbon emissions.
[14]	Albania, Bulgaria, Croatia, Czech Republic, Egypt, Estonia, Hungary, Lithuania, Morocco, Poland, Romania, Slovak Republic, Tunisia, and Türkiye (1995–2014).	Economic growth, energy consumption, sustainable development	Vector Error Correction Model, System Generalized Method of Moments	Bidirectional causality between economic growth and energy consumption. No causality between energy use and sustainable development.

Source: Author.

Based on the above-mentioned recent findings, one can identify that the scientific interest in the Mediterranean region has grown significantly. The region's economic potential is vast, and parallel to this, the region is situated at the forefront of the growth–energy nexus. Despite this fact, the set-up and the findings of the scientific literature on the Mediterranean region's growth–energy nexus are largely fragmented and dissimilar. On the one hand, the Union for the Mediterranean has received little attention in the scientific literature despite its significance in terms of its member countries and sustainability-related targets. On the other hand, contributions either explicitly mention growth, agriculture, or energy use, but a combination of these factors has not yet been analyzed for the members of the Union for the Mediterranean. Hence, the choice of the Union for the Mediterranean member countries regarding the renewable energy–carbon emission nexus is motivated by the analysis of the literature to notice the research gap regarding this region's situation vis-à-vis renewable energy use, agricultural activity, economic growth, and carbon emissions. The results of the literature indicate that the Mediterranean region has not only enormous growth potential, which it has only partially realized, but it has also a problem with carbon emissions since the realization of the growth potential is achieved with mainly fossil energies, for which the demand is expected to grow in the future. In order to counteract the effect, the role of renewable energy sources as well as energy-saving agricultural tools and methods needs to be emphasized, but whether these are already effective or rather a work-in-progress remains unaddressed in the literature.

2. Materials and Methods

The approach follows the methodological toolkit of the contribution by [15] regarding the role of agricultural activity, economic growth, renewable energy use, and carbon emissions, and selects the member countries of the Union for the Mediterranean as the subject of analysis. The Union for the Mediterranean is an intergovernmental organization that consists of all current members of the European Union and 15 non-EU member countries, which are situated in the Southern or Eastern Mediterranean. Despite its brief history, the Union for the Mediterranean aims to increase regional cooperation and dialogue and has two main fields of activity in human development and sustainable development. Regarding its sustainable development activities, the Union for the Mediterranean calls for energy and climate action.

A panel data approach is selected for the analysis, and annual data for all the member countries (except Palestine, Monaco, and Montenegro due to restricted data from these countries) are taken from the World Bank's World Development Indicators. The list of the variables for the years 2002–2018 is given in Table 2. These variables have been taken for the following member countries (in alphabetical order): Albania, Algeria, Austria, Belgium, Bosnia and Herzegovina, Croatia, Cyprus—South, Czech Republic, Denmark, Egypt, Estonia, Finland, Germany, Greece, Hungary, Ireland, Israel, Italy, Jordan, Latvia, Lebanon, Lithuania, Luxembourg, Malta, Mauritania, Morocco, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Syria, Tunisia, and Türkiye. For 37 countries and 17 years, there are 629 observations, which is a suitable number to proceed with quantitative data analysis.

Table 2. List of variables.

Variables	Description	Data Source
Agriculture	Agriculture, forestry, and fishing, value added (% of GDP)	WDI
GDP per Capita	GDP per capita (constant 2015 USD)	WDI
Renewable Energy	Renewable energy consumption (% of total final energy consumption)	WDI
Carbon Emissions	CO_2 emissions (metric tons per capita)	WDI

Source: Author.

As is conventional for panel data, the analysis firstly formulates the generalized functional model in the sense of [15–17] as carbon emissions being a function of GDP per capita, agricultural activity, and renewable energy use. The model is stated in the following equation:

$$(CO_2)_{it} = \text{Intercept} + \text{Agriculture}_{it} + \text{Growth}_{it} + \text{Renewable Energy}_{it} + e_{it}$$

In the equation, CO_2 stands for carbon emissions, agriculture stands for agricultural activity, growth stands for GDP per capita, and renewable energy stands for renewable energy use. In addition, e stands for the residual of the estimation. The equation contains two indices, t for the time series and i for the cross-sections. Prior to the estimation of the model, two issues are being addressed regarding the nature of the data: cross-sectional dependence and stationarity. Cross-sectional dependence is tested with the Pesaran cross-sectional dependence test [18]. The stationarity issue is addressed by means of the cross-sectionally augmented Im–Pesaran–Shin test of unit roots proposed by [19].

Regarding this model specification, the approach firstly proposes a panel fixed effects regression and a panel random effects regression to be compared for selection, where all variables are included in logarithmic (log) terms to decrease multicollinearity. As such, these two models are compared with the Hausman test to identify which model should be chosen. In addition, feasible generalized least squares and difference generalized method of moments estimation are conducted. The feasible generalized least squares approach proves itself to be useful in situations where cross-sectional dependence is observed, since this may lead to biased fixed effects and random effects estimations [20]. The feasible generalized least squares approach is utilized not only for the overall sample, but also for two separate sub-samples that are created by means of separating the member countries regarding their European Union membership. The difference generalized method of moments approach in the sense of [21] proves itself to be a useful estimator especially when the distribution of the error term is not known. When individual fixed effects and the lagged dependent variable are correlated, the estimation is biased in the sense of the endogeneity bias. The difference generalized method of moments estimation solves the endogeneity bias problem that may result when a lagged dependent variable is added to the equation as an independent variable [22].

3. Results

Firstly, descriptive statistics together with the correlation matrix are presented in Tables 3 and 4, respectively. In Table 3, descriptive measures of mean, standard deviation, minimum, median, and maximum can be identified. One can notice that the highest mean is for the GDP per capita as 22,147.369, and the lowest mean is given for agricultural activity as 5.066. In Table 4, one can notice that carbon emissions are negatively correlated with agricultural activity and renewable energy use, whereas they are positively correlated with GDP per capita.

Table 3. Descriptive statistics.

Variable	Carbon Emissions	Agricultural Activity	GDP per Capita	Renewable Energy
Mean	6.295	5.066	22,147.369	15.642
Standard deviation	3.789	5.853	20,721.619	11.861
Minimum	0.455	0.214	891.096	0.059
Median	5.781	2.758	16,160.621	13.000
Maximum	25.669	40.789	112,372.678	52.891
Observations	663	663	663	663

Source: Author's elaboration using R-ExPanDaR package.

Table 4. Correlation matrix.

Variable	Carbon Emissions	Agricultural Activity	GDP per Capita	Renewable Energy
Carbon Emissions	1			
Agricultural Activity	−0.579	1		
GDP per Capita	0.779	−0.541	1	
Renewable Energy	−0.208	0.057	0.008	1

Source: Author's elaboration using R.

Table 5 presents descriptive statistics separately for the European Union member countries of the Union for the Mediterranean and for the non-European Union member countries of the Union for the Mediterranean. Non-European Union member countries are characterized by lower average carbon emissions, higher average agricultural activity, a lower GDP per capita, and an almost equivalent level of renewable energy use in comparison to the European Union member countries.

Table 5. Descriptive statistics for the European Union (EU) member countries of the Union for the Mediterranean and the non-European Union (NEU) member countries of the Union for the Mediterranean.

Variable	Carbon Emissions		Agricultural Activity		GDP per Capita		Renewable Energy	
	EU	NEU	EU	NEU	EU	NEU	EU	NEU
Mean	7.642	3.266	2.440	10.975	29,121.990	6454.474	16.866	12.886
Standard deviation	3.588	2.109	1.579	7.445	20,776.482	8300.164	11.655	11.886
Minimum	2.965	0.455	0.214	1.191	4260.116	891.096	0.087	0.059
Median	7.050	2.676	2.095	9.215	22,682.267	3863.583	14.241	9.749
Maximum	25.669	9.615	12.706	40.789	112,372.678	38,301.454	52.891	42.134
Observations	459	204	459	204	459	204	459	204

Source: Author's elaboration using R-ExPanDaR package.

In Table 6, the results of the cross-sectional dependence test in the sense of Pesaran are presented. Cross-sectional dependence is observed for all variables, as can be seen from the *p*-values of the test statistics, all being smaller than 0.05.

Table 6. Cross-sectional dependence in the sense of Pesaran with log-level variables.

Test Statistic	Carbon Emissions	Agricultural Activity	GDP per Capita	Renewable Energy
CD test value	70.761	71.114	72.327	64.502
p-value	0.000	0.000	0.000	0.000

Source: Author's elaboration using R.

Due to the presence of cross-sectional dependence, cross-sectionally augmented Im–Pesaran–Shin panel unit root tests (CIPS) were conducted in the sense of [19]. The results of the panel unit root tests are presented in Table 7. Firstly, log-level results are presented. These results indicate that all variables are non-stationary, as, for the variables of interest, the corresponding *p*-values are greater than 0.05. When first differences are taken, all variables become stationary, as can be seen from the last column of Table 7, with all *p*-values being smaller than 0.05.

Table 7. CIPS panel unit root tests with log-level variables and log-first difference variables. *p*-values in parentheses.

Variable	Level	First Difference
Carbon Emissions	−1.584 (0.999)	−4.690 (0.000)
Agricultural Activity	−2.505 (0.999)	−4.579 (0.000)
GDP per Capita	−1.1004 (0.999)	−5.190 (0.000)
Renewable Energy	−1.400 (0.999)	−5.554 (0.000)

Source: Author's elaboration using R.

After these preliminary considerations, the next consideration is whether to use fixed effects or random effects for panel data regression analysis. In Table 8, one can identify the results of the Hausman test. A rule of thumb for the Hausman test indicates that a *p*-value (probability) smaller than 0.05 would indicate the selection of the panel fixed effects regression model, whereas the opposite would indicate the selection of the random effects regression model. In this case, the random effects regression model should be chosen since the calculated *p*-value is greater than 0.05.

Table 8. Hausman test.

Chi-Square Statistic	Df	Probability
3.200	3	0.362

Source: Author's elaboration using R.

The results of the random effects regression model are shown in Table 9. The dependent variable of this model is carbon emissions in logarithmic terms and in its first difference. According to Table 9, a one percent increase in economic growth increases carbon emissions by 0.585%. In addition, the relation between renewable energies and carbon emissions is negative and indicates that a one percent increase in the use of renewable energy decreases carbon emissions by 0.125%. Furthermore, the relation between agricultural activity and carbon emissions is positive but not significant.

Table 9. Random effect regression, for the first differences of log variables.

Variable	Coefficient	SE	T-Statistic	*p*-Value
Intercept	−0.011	0.004	−3.014	0.003
Agriculture	0.015	0.024	0.628	0.530
GDP per Capita	0.585	0.072	8.086	0.000
Renewable Energy	−0.125	0.031	−3.969	0.000
R^2	0.257			
Adjusted R^2	0.253			
F-statistic	71.381			0.000

Source: Author's elaboration using R.

Despite a significant F-statistic for the random effects estimation, there is still a possibility that the random effects estimation is biased, given the presence of cross-sectional dependence. To rule out this possibility, a feasible generalized least squares regression analysis was conducted for the first difference of log variables, for which the results are shown in Table 10. For the feasible generalized least squares regression shown in Table 10, the dependent variable is carbon emissions in logarithmic form and in its first difference. The results show that GDP per capita (in its first difference) promotes carbon emissions, and its coefficient is statistically significant given that the *p*-value is smaller than 0.05. On the other hand, the use of renewable energy decreases carbon emissions as the coefficient is statistically significant. In addition, agricultural activity increases carbon emissions; however, the effect is not significant since the *p*-value is greater than 0.05.

Table 10. Feasible generalized least squares regression, for the first differences of log variables.

Variable	Coefficient	SE	T-Statistic	*p*-Value
Intercept	−0.008	0.002	−5.113	0.000
Agriculture	0.015	0.010	1.445	0.147
GDP per Capita	0.518	0.030	17.179	0.000
Renewable Energy	−0.126	0.008	−15.080	0.000
Multiple R^2	0.254			

Source: Author's elaboration using R.

To rule out the possibility of autocorrelation, the approach by [21] was utilized to estimate a difference generalized method of moments (difference-GMM) model in its robust form. The results of the difference-GMM analysis in one-step and two-step variations can be found in Tables 11 and 12, respectively.

Table 11. Difference-GMM, one-step estimation for log variables.

Variable	Coefficient	SE	T-Statistic	Prob.
Lag 1, Carbon Dioxide	0.550	0.096	5.718	0.000
Agriculture	0.017	0.030	0.568	0.570
GDP per Capita	0.285	0.075	3.797	0.000
Renewable Energy	−0.155	0.031	−4.945	0.000
Sargan test	39			0.994
Wald chi-squared	233.467			0.000
Arellano-Bond AR(2)	−1.841			0.066
Observations	585			

Source: Author's elaboration using R.

Table 12. Difference-GMM, two-step estimation for log variables.

Variable	Coefficient	SE	T-Statistic	Prob.
Lag 1, Carbon Dioxide	0.500	0.160	3.112	0.001
Agriculture	0.006	0.034	0.163	0.871
GDP per Capita	0.307	0.139	2.219	0.027
Renewable Energy	−0.152	0.046	−3.283	0.001
Sargan test	26.373			0.999
Wald chi-squared	153.941			0.000
Arellano-Bond AR(2)	−1.568			0.117
Observations	585			

Source: Author's elaboration using R.

For both models, serial correlation of second order as captured by AR(2) cannot be identified. For both models, the Sargan test of overidentifying restrictions has *p*-values greater than 0.05, indicating that both models do not need to be reconsidered. The results of the two-step difference GMM, as can be seen in Table 12, show that renewable energy use has a negative relation with carbon emissions, and the effect is significant at a 1% level. This result indicates that renewable energy use leads to a decrease in carbon emissions in the countries of the Union for the Mediterranean. To be more precise, a 1% increase in renewable energy use decreases carbon emissions by 0.152%, other factors being constant. On the contrary, GDP per capita has a positive relation with carbon emissions, and the effect is statistically significant at a 5% level. To be more specific, a 1% increase in GDP per capita increases carbon emissions by 0.307%, other factors being constant. Furthermore, in this case, the effect of agriculture remains insignificant.

In Tables 13 and 14, the results of two separate feasible generalized least squares regression estimations for non-EU member countries and EU member countries of the Union for the Mediterranean are presented, respectively. In both cases, the dependent variables are carbon emissions in logarithmic form and in first differences for non-EU member countries and EU member countries of the Union for the Mediterranean, respectively. The signs of the effects of economic growth and renewable energy use are confirmed in these estimations. In addition, for the non-EU members of the Union for the Mediterranean, a negative relation between agricultural activity and carbon emissions is captured, which is statistically significant at a 1% level. On the contrary, the relation between agricultural activity and carbon emissions for the EU-member countries seems to be not significant at a 1% level.

Table 13. Feasible generalized least squares regression estimation for non-EU members for the first differences of log variables.

Variable	Coefficient	SE	T-Statistic	Prob.
Intercept	−0.000	0.000	−2.509	0.012
Agriculture	−0.038	0.003	−13.590	0.000
GDP per Capita	0.618	0.007	87.415	0.000
Renewable Energy	−0.092	0.001	−69.005	0.000
Multiple R-Squared	0.285			

Source: Author's elaboration using R.

Table 14. Feasible generalized least squares regression estimation for EU members, for the first differences of log variables.

Variable	Coefficient	SE	T-Statistic	Prob.
Intercept	−0.132	0.001	−10.519	0.000
Agriculture	0.019	0.008	2.319	0.020
GDP per Capita	0.534	0.023	22.782	0.000
Renewable Energy	−0.158	0.008	−20.521	0.000
Multiple R-Squared	0.236			

Source: Author's elaboration using R.

4. Discussion

To start with, one can identify an overall positive relation between economic growth (captured as GDP per capita in the analysis) and carbon emissions. This confirms the existing findings of [3] and [13] and contributes to the discussion around the growth–carbon emissions nexus. The most famous contribution in this field is the so-called Environmental Kuznets Curve hypothesis, which proposes a positive relation between carbon emissions and economic growth for the earlier phases of economic development, but from a certain development threshold onwards, these emissions decline, since the economy can afford environmentally friendly technologies [23]. Previous research [4] indicates that this shift does not automatically reflect itself in economic performance in the short run, but rather takes time until its impact on economic growth can be observed. As such, countries—including countries of the Union for the Mediterranean—have a trade-off between current fossil-based growth and future sustainable growth, and very often, the current growth perspective outweighs the future growth perspective, since it takes time, effort, and resources to reach a similar level of economic performance with environmentally friendly technologies. One problem that may come from a straightforward interpretation of this issue may be to imply a reduction in growth aspirations; however, this is not considerable [23]. As such, instead of reducing the growth aspiration, a long-term focus on implementing renewable energies and further developing their efficiency and carbon-reducing impact needs to be planned, by bringing together multiple stakeholders.

This leads to the second conclusion of the empirical analysis—renewable energies reduce carbon emissions. This finding confirms the results of [13] and indirectly also those of [8]. Renewable energies are considered as innovations that can enhance environmentally friendly technologies to reduce carbon emissions and improve environmental quality [23]. In this sense, one can notice that separate results from non-EU and EU member countries of the Union for the Mediterranean bring similar conclusions regarding the impact of renewable energy use on carbon emissions. This impact can be highlighted twofold: on the one hand, the relation between renewable energy use and carbon emissions is significant and positive in both groups of countries, which indicates that renewable energy use is no longer something specific to the EU, or something only affordable by the EU; on the other hand, the relative magnitude in comparison to the magnitude of the impact coming from economic growth is similar in both cases. Referring to the feasible generalized least squares regression estimation analysis presented in Tables 13 and 14, a 1% increase in renewable energy use decreases carbon emissions by 0.092% (non-EU countries) and 0.158% (EU countries), respectively. In comparison, a 1% increase in economic growth increases carbon emissions by 0.618% (non-EU countries) and 0.534% (EU countries), respectively. In this comparison, in both cases, the relative magnitude of the use of renewable energies on carbon emissions is smaller than the effect created by economic growth. This calls for more action towards further developing renewable energies that are not only affordable for the masses, but also create the desired impact.

The third issue identified from the analysis is regarding the role of agricultural activity and carbon emissions. The results of the random effects regression estimation, difference generalized method of moments regression estimation, and feasible generalized least squares regression estimation do not display any significant impact of agricultural activity on carbon emissions. However, separate analyses of non-EU and EU member countries indicate that for the group of non-EU member countries, there is a negative and significant effect. This is captured by the results in Table 13. According to these results, a 1% increase in agricultural activity in non-EU member countries decreases carbon emissions by 0.038%. This finding is in line with the findings of [24–26], confirming a negative relation for African countries and G7 countries, respectively. Not only are Mediterranean countries suitable for making use of existing renewable energy sources such as solar-PV systems, low-enthalpy geothermal energy, solid biomass burning, co-generation systems, high-efficiency heat pumps, and the reuse of rejected industrial heat [27], but there are also attempts to systematize existing renewable energy usage methods in agriculture to progress on a country level [28]. The approach by [29] delivers empirical evidence of how agricultural innovations influence the Turkish economy by referring to public–private partnerships such as research institutes collaborating with seed companies, which enable financing for the research and development expenses of these institutes. Similarly, [30] deliver empirical evidence of the use of renewable energy in agricultural activities in Türkiye. These are, for instance, food drying by using solar energy, soil solarization instead of methyl bromide use for controlling soil-borne pathogens and pests, agricultural irrigation using solar energy, geothermal energy use in agriculture, and hydropower plants. Similarly, [31] delivers empirical evidence from Morocco regarding its biomass potential that is utilized for agricultural activity, whereas [24] emphasize the transformation of Tunisia to make use of renewable energy innovations in agricultural activities. Even though some of these attempts are backed by the European Union, it is obvious that they have created a greater impact in these countries, which rely more on agricultural activity in comparison to their European Union member counterparts. With respect to the Union for the Mediterranean, an attempt towards sustainable, climate-smart, and organic agriculture was made by signing a Memorandum of Understanding with the Food and Agriculture Organization of the United Nations (FAO) and the International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM) in January 2021 [32]. Overall, the magnitude of the impact of agricultural activity on carbon emissions is relatively small compared to that of GDP growth or renewable energies; however, recent developments indicate that making use of new methods and management tools in agriculture has the potential to mitigate carbon emissions.

5. Conclusions, Policy Implications, and Limitations

This contribution investigated the relation between carbon emissions, economic growth, renewable energy use, and agricultural activity. This analysis was conducted for 37 members of the Union for the Mediterranean over the period 2002–2018. The data analysis started with descriptive statistics and correlations, moved on to test for cross-sectional dependence and unit roots, and presented a panel random effects regression estimation based on the results of the Hausman test. Since cross-sectional dependence may bias the results of the random effects model, a feasible generalized least squares regression estimation was conducted. In addition, to rule out the possibility of autocorrelation, a difference generalized method of moments model was estimated both in one-step and two-step versions. Finally, separate feasible generalized least squares regression estimations were conducted for non-EU and EU member countries from the Union for the Mediterranean.

The results confirmed that economic growth positively influences carbon emissions, whereas renewable energy use negatively influences carbon emissions. The effect of agriculture was insignificant for the entire sample (for random effects, feasible generalized least squares, and difference generalized method of moments estimation), significant and negative for the non-EU sample (for feasible generalized least squares estimation), and insignificant for the EU sample.

This contribution has the following policy implications. Firstly, economic growth for the Union for the Mediterranean countries comes with a cost—carbon emissions. Policymaking on the Union level should further enhance efforts to balance between growth ambitions and sustainable development. Thus far, only partial solutions (e.g., with respect to food systems as mentioned above) have come from the Union, with no comprehensive plans. Secondly, renewable energy use in the Union for the Mediterranean countries decreases carbon emissions, albeit only with a small impact. The magnitude of the impact does not yet outweigh the impact of economic growth on increasing carbon emissions. Therefore, research and development efforts need to focus on improving the existing renewable energy methods and developing new ones for successful implementation and emission mitigation. Thirdly, regarding agricultural activity, the analysis identifies that a correct mix of new technological tools and methods and new managerial perspectives can decrease the footprint of agriculture over the long term. It is known that many countries involved in the Union for the Mediterranean aim to achieve sustainable agricultural practices, and this evidence calls for more collaboration to combine agricultural insights with innovations on both technological and managerial levels to mitigate against emissions and adapt to the challenges of climate change.

This contribution has the following limitations. Firstly, it did not consider the role of environmental regulations in the setup of carbon emissions. From the previous literature, it is known that reinforcing environmental regulations can have a prolonged impact on the sustainable development of an economy, also by reducing carbon emissions [33]. Hence, further research can concentrate on whether environmental regulations are strong enough to contribute to the sustainable economic development of the Mediterranean region. Secondly, due to data limitations, the current contribution was not able to capture the developments of the last 4 years. From the contribution of [1], for instance, it is clear that the last 4 years were a period of radical change regarding energy security and energy diversity issues. Whether and how these have an impact on carbon emissions remain open, and it is the duty of further research to concentrate on capturing the impact of these efforts in a statistically meaningful and significant way. Thirdly, despite its wide use and acceptance, the contribution made use of the average values of the variables of interest, which may only provide a weak perspective to establish better associations. Consequently, further research should emphasize case-based and national-level analyses to help specific countries with their energy and agricultural policies. In this instance, the use of national databases and cases can deliver valuable insights to understand the most recent developments vis-à-vis the renewable energy–carbon emission nexus.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data can be found from the World Development Indicators of the World Bank: https://databank.worldbank.org/source/world-development-indicators (accessed on 4 April 2022).

Acknowledgments: The author thanks the four anonymous reviewers for their constructive comments.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Albayrak, B. *Burası Çok Önemli! Enerjiden Ekonomiye Tam Bağımsız Türkiye*; Turkuvaz: İstanbul, Turkey, 2022.
2. Alola, A.A.; Alola, U.V. Agricultural land usage and tourism impact on renewable energy consumption among Coastline Mediterranean Countries. *Energy Environ.* **2018**, *29*, 1438–1454. [CrossRef]
3. Yıldırım, S.; Yıldırım, D.Ç.; Aydın, K.; Erdoğan, F. Regime-dependent effect of tourism on carbon emissions in the Mediterranean countries. *Environ. Sci. Pollut. Res.* **2021**, *28*, 54766–54780. [CrossRef]
4. Sharma, G.D.; Tiwari, A.K.; Erkut, B.; Mundi, H.S. Exploring the nexus between non-renewable and renewable energy consumptions and economic development: Evidence from panel estimations. *Renew. Sustain. Energy Rev.* **2021**, *146*, 111152. [CrossRef]
5. Belaïd, F.; Zrelli, M.H. Renewable and non-renewable electricity consumption, environmental degradation and economic development: Evidence from Mediterranean countries. *Energy Policy* **2019**, *133*, 110929. [CrossRef]
6. Union for the Mediterranean. Energy and Climate Action. Available online: https://ufmsecretariat.org/what-we-do/energy-and-climate-action/ (accessed on 4 April 2022).
7. Union for the Mediterranean. *Regional Analysis on Nationally Determined Contributions*; Union for the Mediterranean: Barcelona, Spain, 2021.
8. Demircan Çakar, N.; Gedikli, A.; Erdoğan, S.; Yıldırım, D.Ç. A comparative analysis of the relationship between innovation and transport sector carbon emissions in developed and developing Mediterranean countries. *Environ. Sci. Pollut. Res.* **2021**, *28*, 45693–45713. [CrossRef]
9. Belaid, F.; Boubaker, S.; Kafrouni, R. Carbon emissions, income inequality and environmental degradation: The case of Mediterranean countries. *Eur. J. Comp. Econ.* **2020**, *17*, 73–102. [CrossRef]
10. Zrelli, M.H. Renewable energy, non-renewable energy, carbon dioxide emissions and economic growth in selected Mediterranean countries. *Environ. Econ. Policy Stud.* **2017**, *19*, 691–709. [CrossRef]
11. Zafeiriou, E.; Azam, M. CO_2 emissions and economic performance in EU agriculture: Some evidence from Mediterranean countries. *Ecol. Indic.* **2017**, *81*, 104–114. [CrossRef]
12. Alola, A.A.; Alola, U.V.; Akadiri, S.S. Renewable energy consumption in Coastline Mediterranean Countries: Impact of environmental degradation and housing policy. *Environ. Sci. Pollut. Res.* **2019**, *26*, 25789–25801. [CrossRef] [PubMed]
13. Ulucak, R.; Erdogan, F.; Bostanci, S.H. A STIRPAT-based investigation on the role of economic growth, urbanization, and energy consumption in shaping a sustainable environment in the Mediterranean region. *Environ. Sci. Pollut. Res.* **2021**, *28*, 55290–55301. [CrossRef] [PubMed]
14. Latief, R.; Kong, Y.; Peng, Y.; Javeed, S.A. Conceptualizing Pathways of Sustainable Development in the Union for the Mediterranean Countries with an Empirical Intersection of Energy Consumption and Economic Growth. *Int. J. Environ. Res. Public Health* **2020**, *17*, 5614. [CrossRef]
15. Naseem, S.; Guang Ji, T. A system-GMM approach to examine the renewable energy consumption, agriculture and economic growth's impact on CO_2 emission in the SAARC region. *GeoJournal* **2021**, *86*, 2021–2033. [CrossRef]
16. Berk, I.; Kasman, A.; Kılınç, D. Towards a common renewable future: The System-GMM approach to assess the convergence in renewable energy consumption of EU countries. *Energy Econ.* **2020**, *87*, 103922. [CrossRef]
17. Destek, M.A.; Balli, E.; Manga, M. The Relationship between CO_2 Emission, Energy Consumption, Urbanization and Trade Openness for Selected CEECs. *Res. World Econ.* **2016**, *7*, 52–58. [CrossRef]
18. Pesaran, M.H. Testing Weak Cross-Sectional Dependence in Large Panels. *Econom. Rev.* **2015**, *34*, 1089–1117. [CrossRef]
19. Pesaran, M.H. A simple panel unit root test in the presence of cross-section dependence. *J. Appl. Econom.* **2007**, *22*, 265–312. [CrossRef]
20. Erzurumlu, Y.Ö.; Gözgör, G. Effects of economic policy uncertainty on energy demand: Evidence from 72 countries. *J. Chin. Econ. Bus. Stud.* **2022**, *20*, 23–38. [CrossRef]
21. Arellano, M.; Bond, S. Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *Rev. Econ. Stud.* **1991**, *58*, 277. [CrossRef]
22. Gnangoin, Y.T.B.; Du, L.; Assamoi, G.; Edjoukou, A.J.; Kassi, D.F. Public Spending, Income Inequality and Economic Growth in Asian Countries: A Panel GMM Approach. *Economies* **2019**, *7*, 115. [CrossRef]
23. Rahman, M.M.; Alam, K. CO_2 Emissions in Asia-Pacific Region: Do Energy Use, Economic Growth, Financial Development, and International Trade Have Detrimental Effects? *Sustainability* **2022**, *14*, 5420. [CrossRef]
24. Ben Jebli, M.; Ben Youssef, S. The role of renewable energy and agriculture in reducing CO_2 emissions: Evidence for North Africa countries. *Ecol. Indic.* **2017**, *74*, 295–301. [CrossRef]

25. Rafiq, S.; Salim, R.; Apergis, N. Agriculture, trade openness and emissions: An empirical analysis and policy options. *Aust. J. Agric. Resour. Econ.* **2016**, *60*, 348–365. [CrossRef]
26. Wang, L.; Vo, X.V.; Shahbaz, M.; Ak, A. Globalization and carbon emissions: Is there any role of agriculture value-added, financial development, and natural resource rent in the aftermath of COP21? *J. Environ. Manag.* **2020**, *268*, 110712. [CrossRef] [PubMed]
27. Vourdoubas, J. Creation of Net Zero Carbon Emissions Agricultural Greenhouses Due to Energy Use in Mediterranean Region; Is it Feasible? *J. Agric. Crop.* **2020**, *6*, 89–95. [CrossRef]
28. Erdin, C.; Ozkaya, G. Turkey's 2023 Energy Strategies and Investment Opportunities for Renewable Energy Sources: Site Selection Based on ELECTRE. *Sustainability* **2019**, *11*, 2136. [CrossRef]
29. Akkoyunlu, Ş. *Agricultural Innovations in Turkey*; Swiss National Centre of Competence in Research: Bern, Switzerland, 2013.
30. Bayrakcı, A.G.; Koçar, G. Utilization of renewable energies in Turkey's agriculture. *Renew. Sustain. Energy Rev.* **2012**, *16*, 618–633. [CrossRef]
31. Boulakhbar, M.; Lebrouhi, B.; Kousksou, T.; Smouh, S.; Jamil, A.; Maaroufi, M.; Zazi, M. Towards a large-scale integration of renewable energies in Morocco. *J. Energy Storage* **2020**, *32*, 101806. [CrossRef] [PubMed]
32. Union for the Mediterranean. Promoting food Systems Transformation in the Mediterranean towards 2030. Available online: https://ufmsecretariat.org/food-systems-transformation-mediterranean/ (accessed on 5 April 2022).
33. Nathaniel, S.P.; Murshed, M.; Bassim, M. The nexus between economic growth, energy use, international trade and ecological footprints: The role of environmental regulations in N_{11} countries. *Energy Ecol. Environ.* **2021**, *6*, 496–512. [CrossRef]