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The Linkage between Economic Growth, Renewable Energy, Tourism, CO_2 Emissions, and International Trade: The Evidence for the European Union

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Abstract: This paper evaluates the link between economic growth, renewable energy, tourism arrivals, trade openness, and carbon dioxide emissions in the European Union (EU-28). As an econometric strategy, the research uses panel data. In the first step, we apply the unit root test, and the results demonstrated that the variables used in this study are integrated I (1) in the first difference. In the second step, we apply the Pedroni cointegration test, and Kao Residual cointegration test, and we observe that the variables are cointegrated in the long run. The panel fully modified least squares (FMOLS), panel dynamic least squares (DOLS), and generalized moments system (GMM-System) estimator are considered in this research. The econometric results proved that trade openness and renewable energy decreased climate change and environmental degradation. The empirical study also found a positive effect of economic growth on carbon dioxide emissions. Moreover, tourism arrivals are negatively correlated with carbon dioxide emissions, showing sustainability practices of the tourism sector on the environment. Furthermore, carbon dioxide emissions in the long run present a positive impact, indicating that climate change increases. In this study, we also consider the recent methodology of Dumitrescu–Hurlin to observe the causality and the relationship between renewable energy, trade openness, economic growth, tourism arrivals, and carbon dioxide emissions.

Keywords: environmental damage; renewable energy; trade openness; tourism; panel cointegration; GMM-System estimator

1. Introduction

The correlation between economic growth and the energy economy has always been associated with energy efficiency and energy demand. There are numerous studies [1,2] that assess this relationship by demonstrating that non-renewable energy increases environmental damage, namely climate change, and global warming. Many of these studies use macroeconomic variables and are applied to a set of countries (panel data) or to a country (time series). However, there are also studies applied to a specific sector such as the agricultural sector (e.g., [3–5]) that also validate this relationship, reaching similar conclusions.

International conferences on environmental damage and preservation of the environment, such as the Kyoto Protocol, Paris Agreement (2015), or the Directive 2009/28/EC, have enabled the use of renewable energy to be promoted. Researchers began to analyze the impact of renewable energies on economic growth and climate change (e.g., [6–10]), this realization being closer to sustainable development. Directive 2009/28/EC made European states and their governments invest more in renewable energies, demonstrating that they are efficient from a long-term perspective.

Another concern of human ecology and energy efficiency is the relationship between the tourism sector and environmental issues. The debate in the academic and scientific community over the past two decades has been extensive. Scientific studies and reports by the World Tourism Organization (WTO) demonstrate that the tourism sector is vital to the economic growth of economies and promotes employment. Opinions are divided on the relationship between tourism and climate change. We have empirical studies that support the idea that tourism accentuates climate change and other studies that prove that there is a negative correlation between tourist arrivals and carbon dioxide emissions; that is, tourism may be a promotional agent for improving damage (e.g., Balsalobre-Lorente et al. [10]; Imran et al. [11]). We will analyze this topic in the literature review. The debate over the relationship between trade openness and environmental issues since the 1990s has sparked the interest of economic science (e.g., Grossman and Krueger [12], Leitão [13], Sinha, et al. [2], and Roy [14]). Academics are unanimous that the impact of trade openness on environmental damage depends on developing countries' levels of development. If countries are in a phase of industrial development, the use of renewable energies and the common trade agreements that promote intra-industry trade, it appears that there is a decrease in carbon dioxide emissions, that is, trade can be a promoting agent of sustainable development, for example, if countries belong to the same optimal currency zone.

This study analyzes the complexity of the relationships between economic growth, renewable energy, and carbon dioxide emissions. The impact of tourist arrivals and international trade on climate change is also assessed in this survey for the 28 countries of the European Union (EU-28) for the period 1995–2014. In methodological terms, we use panel data, namely cointegration (the panel fully modified least-squares—FMOLS, panel dynamic least squares—DOLS), and generalized moments system method (GMM-System). We consider the GMM-System because this estimator allows solving serial correlation problems and the endogeneity of independent variables that are persistent in this type of study.

This investigation seeks to contribute to the literature in several ways. At first, we surveyed the most relevant research that allows us to assess the linkage between economic growth, renewable energy, trade openness, tourism arrivals, and climate change. In a second step, we evaluate this complexity through dynamic models, which allows us to assess the short- and long-term effects. Finally, the article presents some conclusions regarding the study under analysis that may serve as a debate for the academic community, as well as policymakers.

The paper is prepared as follows. The second section analyzes the literature review. Section 3 shows the materials and methods used in the empirical study. The econometric results are presented in Section 4, and the final section concludes.

2. Literature Review

In this section, the most relevant empirical studies are presented to clarify the relationship between economic growth, renewable energy, tourism arrivals, and climate change. The linkage between trade openness and environmental damage is also studied in this research.

The correlation between economic growth and carbon dioxide emissions were studied in the 1990s, for instance, Grossman and Krueger [12,15], and Douglas and Selden [16] showed that economic activities stimulate climate change and greenhouse gas emissions.

The literature of the environmental Kuznets curve (EKC) is very abundant. The researchers use, in general, two different types of methodologies, i.e., multivariate time series (ARDL—autoregressive distributed lag, VECM—vector error correction model, Granger causality), and panel data (OLS—ordinary least squares, fixed effects, random effects, GMM-System, or Panel cointegration). The studies of Alshehry and Belloumi [17], Balogh and Jambor [4], Dogan and Inglesi-Lotz [18], and Mania [19], found a positive impact of income per capita on carbon dioxide emissions. Moreover, the relationship between economic growth, carbon dioxide emissions, and health expenditures was investigated by Nafngiyana et al. [20] and applied to ASEAN—Association of Southeast Asian Nations for the period 2008–2019, using the GMM-DIF (Generelized Method of Moments at first difference) and GMM-System. The authors proved that carbon dioxide emissions present a positive sign with the GMM-DIF and GMM-System, demonstrating that climate change increased in the long run. The variable of economic growth shows a positive effect on CO_2 emissions with the GMM-DIF estimator. The variables of health expenditure per capita, urban population, and trade are positively correlated with carbon dioxide emissions. In this context, Dogan and Inglesi-Lotz [18] investigated the EKC in the seven European countries for the period 1980–2014. The authors used, as an econometric strategy, the panel cointegration (Pedroni, panel fully modified least squares—FMOLS, and panel dynamic least squares—DOLS), and the results confirmed the hypotheses of the EKC, i.e., a positive correlation between income per capita and CO_2 emissions, and a negative relationship between squared income per capita and CO_2 emissions.

Moreover, the empirical study of Mania [19] evaluated the EKC hypothesis by 98 countries for the period 1995–2013. The authors applied the GMM-System and pooled mean group (PMG) estimators, and the econometric results showed that export diversification presents a negative sign on CO_2 emissions. The arguments of the EKC are valid, i.e., an inverted U-shaped curve. In this line, the empirical study of Balogh and Jambor [4] evaluates the EKC hypothesis for 169 countries, using dynamic panel data (GMM-System estimator), and their results are in accord with the EKC assumptions. These authors found a positive effect of nuclear energy and carbon dioxide emissions. However, renewable energy allows for decreasing CO_2 emissions. Subsequently, tourism arrivals and international trade improve environmental degradation. In this line, the relationship between carbon dioxide emissions, urbanization, and globalization was investigated by Leitão and Shahbaz [21]. The authors tested the assumptions of the EKC for 18 countries, applying the GMM-System estimator. The link between economic growth and CO_2 emissions was found to be an inverted U-shaped curve. The variables of globalization (KOF index) and energy consumption are positive with CO_2 emissions. As well, the urban population and corruption present a negative effect on carbon dioxide emissions.

The empirical study of Burakov [3] considered the arguments of EKC hypotheses, and applied the autoregressive distributed lag (ARDL) bounds test and the Granger causality test to the Russia case. Considering the results of the ARDL model, in the long run, the author found a positive correlation between the agriculture sector and CO_2 emission. Moreover, the study presents a positive impact of energy consumption on carbon dioxide emissions. Relative to the hypotheses of the EKC, Burakov [3] proves an inverted U-shaped curve.

Güney and Kantar [22] analyzed the link between biomass energy consumption and sustainable development in OECD countries for the period 1990–2017, using the GMM-System, and the authors found a positive effect of lagged variables of sustainable development. Furthermore, the variables of biomass energy, non-renewable energy, and income per capita present a positive impact on sustainable development.

Gessesse and He ([23], p. 188) explained the connection between Chinese economic growth, carbon dioxide emissions, and energy consumption using the ARDL bounds test for the period 1971–2015. In the long run, the authors proved that energy consumption and economic growth have a positive impact on carbon dioxide emissions. Additionally, the variables of squared income per capita and lagged carbon dioxide emissions present a negative sign, which is statistically significant at a 1% level.

The relationship between renewable energy and CO_2 emissions has received attention in academic studies in recent years, such as Bilan et al. [24], Acheampong et al. [25], Zoundi [26], and Liu et al. [27]; the researchers found a negative association between renewable energy and carbon dioxide emissions, referring to the fact that renewable energy allows decreasing climate change and greenhouse gas. In this context, the empirical study of Jebli et al. [28] applied panel data for Central and South American countries for the period 1995–2010. The authors used FMOLS, DOLS cointegration estimators, and Pairwise Granger causality tests, and the results show that carbon dioxide emissions decreased in the long run. Moreover, the variables of renewable energy, international trade, tourism arrivals, and foreign direct investment present a negative effect in the long run.

The effects of renewable energy consumption, agriculture activity, and economic growth on carbon dioxide emissions in SAARC countries' experience was investigated by Nassen and Ji [29] for the period 2000–2017. The authors applied the fixed effects estimator and GMM-System. The coefficients obtained by dynamic panel data proved that renewable energy and agricultural activity are negatively correlated with CO_2 emissions. However, the variable of income per capita shows that economic growth stimulates climate change; i.e., there exists a positive impact of income per capita on carbon dioxide emissions.

The reports of the World Tourism Organization (WTO) show that tourism activity has been increasing, and this sector is essential for the economic growth of economies. There exist numerous studies that assess the relationship between tourist inflows and economic growth. There is another category of studies that focus on the determinants of tourism demand, such as Wambove et al. [30], Harb, and Bassil [31], and Mitra [32].

Regarding the effect of tourist inflows on CO_2 emissions, the studies are not unanimous, i.e., we have two different perspectives. Nepal et al. [33], Shakouri et al. [34], Işik et al. [35], Sharif et al. [36], conclude that the tourism sector stimulates climate change and global warming. However, if we look at the WTO's considerations, the tourism sector should be associated with sustainable practices; in this line, the empirical studies found a negative association between tourist arrivals and carbon dioxide emissions. The academic papers of Lee and Brahmasrene [37], Jebli et al. [38], Jebli et al. [28], Katircioglu et al. [39], Leitão and Shabaz [40], Balsalobre-Lorente et al. [10] validate the hypothesis of sustainability between tourist arrivals and carbon dioxide emissions. Besides, the empirical study of Balsalobre-Lorente et al. [10], applied to OECD developed countries for the period 1994–2014, proves an inverted U-shaped curve between tourism arrivals and CO_2 emissions. The authors concluded that, in the long run, the tourism sector allows the use of sustainable practices that encourage environmental awareness, and consequently, a decrease in climate change and greenhouse gas. In the context of the EU experience, the empirical study of Leitão and Shabaz [40], using panel data (OLS, fixed effects, random effects, and GMM-System) for the period 1990–2009, proves that tourism demand is negatively correlated with carbon dioxide emissions. The authors justify this result based on the concept of sustainable tourism, stating that tourist visitors seek tourist destinations where there are concerns about sustainability and the environment.

Theories of optimal momentary zones and economic integration demonstrate that the formation of a common market promotes fairer trade within the same regional block. Since commercial and tariff barriers are eliminated among the economies that are part of the same regional block, in this context, international trade and the rules of trade policy demonstrate that international trade promotes a sustainable environmental policy, facilitating a reduction in ecological damage. In this line, studies by Roy [14], Cole et al. [41], Sun et al. [42], and Leitão and Balogh [43] demonstrate that international trade makes it possible to reduce climate change. Sun et al. (2019) examined the linkage between trade openness and CO_2 emissions. The authors used Pedroni cointegration, panel fully modified least squares, and the vector error correction model (VECM). Their results demonstrated an inverted U-shaped curve between international trade and carbon dioxide emissions. Besides, Balsalobre-Lorente et al. [10] conclude that the liberalization of the market measured by the globalization index is negatively correlated with CO_2 emissions in the long run.

The empirical study of Sun et al. [42] considered the impact of trade openness on CO_2 emissions for the period 1991–2014. The authors used the methodology of FMOLS and the vector error correction model (VECM), and they found a negative correlation between trade openness and CO_2 emissions for Southeast Asia and Europe. The variables of income per capita and energy consumption present a positive impact on carbon dioxide emissions for Southeast Asia, Central Asia, the Middle East/Africa, South Asia, and Europe. In this line, Sinha et al. [2] used a GMM estimator. Their results showed that income per capita and squared income per capita are positively and negatively correlated with carbon dioxide emissions, respectively. The results also proved that trade openness and renewable energy consumption are negatively associated with CO_2 emissions.

Recently, the empirical study of Leitão and Balogh [43] tested the effect of agricultural intra-industry trade on climate change for the case of EU countries, considering the period 2000–2014. The authors used, as econometric strategies, fixed effects and the GMM-System, and the econometric results showed that intra-industry trade is negatively correlated with carbon dioxide emissions. Moreover, the empirical study proved that renewable energy is negatively associated with CO_2 emissions, and agricultural productivity encourages greenhouse effects.

3. Materials and Methods

This study considers the impacts of economic growth, renewable energy, tourism arrivals, and international trade on carbon dioxide emissions (CO_2) for the period 1995–2014. Following Leitão and Balogh ([43], p. 207), it is possible to verify that older EU member countries like Cyprus, Portugal, Spain, Germany, France, and the United Kingdom have been responsible for the emissions of carbon dioxide. Besides, the importance of the new member states such as Lithuania, Latvia, Romania, and Estonia should be mentioned. In this context, the sample is collected by the European Union (EU-28 countries) using panel data. The dataset covers the old and the new States of the EU, allowing an overview of all member countries. We apply the panel unit root test considering the methodology of Augment Dickey–Fuller (ADF)–Fisher Chi-square, and Phillips–Perron [44], to check if the variables used in this study are stationary at level. In this line, and following the literature, if the variables have the unit root at level, the researchers should be verifying if the variables are integrated in differences I (1). The relationship between variables, in the long run, was confirmed by panel data cointegration Pedroni [45,46], and Kao Residual Cointegration Test [47]. The model was estimated by the panel fully modified least squares (FMOLS), and panel dynamic least squares (DOLS), and generalized moments system method (GMM-System estimator). The Pedroni [48] cointegration test is considered by with-dimension (panel cointegration), and between -dimension (mean panel). It is considered with-dimension when it includes four groups of tests: panel v-statistic (nonparametric, used on the variance ratio), panel-rho statistics, panel PP-statistic, and panel ADF-static. In between-dimension (mean panel), the residuals are considered by three statistics: group rho-statistic; group PP-statistic; group ADF-statistic.

The Kao residual cointegration test [47] is a complementary test that allows analysis of whether or not there is cointegration.

In the methodology proposed by Phillips and Hansen [49], FMOLS permits evaluation of the long-run relationship among the variables. In this line, Saikkonen [50] and Stock and Watson [51] presented a complementary DOLS methodology.

As in the previous studies of Leitão [52], Leitão and Shabaz [21], and Jambor and Leitão [53] referred to the static panel (OLS—ordinary least squares, fixed effects, random effects) as having problems of serial correlation and the endogeneity of independent variables. The estimator of the system generalized moments method, (GMM-System) proposed by Arellano and Bover [54], and Blundell and Bond [55] is an alternative to first differenced Generalized Moments Method (GMM-DIF). The GMM-System allows solving the econometric problems such as serial correlation, and the endogeneity of independent variables. According to Leitão [52], Leitão and Shabaz [21], Jambor and Leitão [53], Mania [19], and Nassen and Ji [29], the GMM-System is consistent if there is no second serial correlation [AR2], and if the instruments used are valid (Sargan test). The empirical study also considers the causality between the variables used in this research by the Dumitrescu–Hurlin [56] pairwise causality test (H0: homogenous non-causality; H1: heterogenous non-causality).

Model Specification and Theoretical Hypotheses

Considering the previous studies of Leitão and Shabaz [21], Sinha et al. [2], Balsalobre-Lorente et al. [10], Jebli et al. [28], and Mania [19], the next function is recognized in Equation (1):

$$CO_2 = f\ (GDP, REN, TOURISM, TRADE) \quad (1)$$

$$\text{LogCO}_{2it} = \alpha_0 + \alpha_1\text{LogGDP}_{it} + \alpha_2\text{LogREN}_{it} + \alpha_3\text{LogTOURISM}_{it} + \alpha_4\text{LogTRADE}_{it} + \delta_t + \eta_{it} + \varepsilon_{it} \quad (2)$$

In this empirical study, we use as a dependent variable, the logarithm of carbon dioxide emission (CO_2) in kilotons to evaluate the climate changes. The data is sourced from the World Bank, where *i* represents the number of countries, i.e., EU-28, and *t* signifies the time period. All variables are expressed in logarithm form because the estimates can be read by elasticities. The explanatory variables considered are the logarithm of income per capita (*GDP*) expressed in US dollars, the logarithm of renewable energy (*REN*), i.e., the percentage of renewable energy in total final energy, the logarithm of tourism arrivals (*TOURISM*), considering the overnight visitors from the World Tourism Organization, and the logarithm of trade openness (*TRADE*).

The variable of trade openness assumes the following expression:

$$TRADE = \frac{(X+M)}{GDP} \quad (3)$$

where *X*—represents the total exports, *M*—signifies the total of imports, and *GDP*—gross domestic product.

The data for the variables of income per capita, renewable energy, and trade openness is sourced from the World Bank Indicators; δ_t—signifies the common determinist trend; η_{it}—represents the unobserved time, and ε_{it}—is a random disturbance.

The dynamic panel data (GMM-System) assumes the following expression:

$$\text{LogCO}_{2it} = \alpha_0 + \alpha_1\text{LogCO}_{2it\text{-}1} + \alpha_2\text{LogGDP}_{it} + \alpha_3\text{LogREN}_{it} + \alpha_4\text{TOURISM}_{it} + \alpha_5\text{LogTRADE}_{it} + \delta_t + \eta_{it} + \varepsilon_{it} \quad (4)$$

In the next step, we formulate the hypothesis considering the literature review presented in the last section.

Hypothesis 1 (H1). *There is a positive relationship between income per capita and carbon dioxide emissions.*

There is a consensus that economic growth encourages climate change and environmental damage. Economic activities are related to climate change and greenhouse emissions. The carbon dioxide emissions occurred because manufacturing and industry use non-clean energy consumption. The recent empirical studies of Dogan and Inglesi-Lotz [18], Burakov [3], and Gessesse and He [23] give support to our hypothesis. According to the empirical studies, there exists a positive impact of income per capita *(GDP* > *0*) on CO_2 emissions.

Hypothesis 2 (H2). *Climate change decreased among economies that use renewable energy.*

Cleaner energy encourages economic development, and consequently, an increase in growth.

The Directive 2009/28/EC and the Paris Agreement (2015) promoted renewable energy use in the EU. The recent empirical studies of Nassen and Ji [29], Vasylieva et al. [57], Acheampong et al. [25], Liu et al. [27], and Bilan et al. [24] found a negative correlation between renewable energy and CO_2 emissions (*REN* < *0*). These studies demonstrated that renewable energy stimulates sustainable development.

Hypothesis 3 (H3). *Sustainable Tourism practices promote environmental awareness, and a decrease in climate change.*

Considering the arguments of the World Tourism Organization (WTO) and the EU agenda, tourism sustainability focuses on the use of sustainable resources, taking into account biodiversity and the socio-cultural respect and tolerance of the population.

The empirical studies of Lee and Brahmasrene [37], Jebli et al. [38], Jebli et al. [29], Katircioglu et al. [39], Leitão and Shabaz [40] and Balsalobre-Lorente et al. [10] proved that the tourism sector encourages sustainable environmental practices. Based on the literature review, the dominant paradigm considers a negative impact of tourism arrivals (*TOURISM* < *0*) on CO_2 emissions.

Hypothesis 4 (H4). *Trade openness promotes the environmental system.*

Theories of economic integration demonstrate that the common trade rules have the objectives of sustainable practices and a reduction in environmental damage. In EU-28, the standard environmental policy and the common commercial policy promote sustainable practices to reduce carbon dioxide emissions and climate change.

Innovation and product differentiation encourage environmental sustainability. There is a vast literature about this relationship. Furthermore, Sinha et al. [2], Balsalobre-Lorente et al. [10], Sun et al. [42], Leitão, and Balogh [43] found a negative association between trade openness (*TRADE* < *0*) and climate change, i.e., international trade encourages environmental sustainability.

4. Results and Discussion

In this section, we present the empirical results to test the linkage between economic growth, renewable energy, tourism arrivals, trade openness, and carbon dioxide emissions. In this context, we start to analyze the general statistics, and panel unit root test, considering the analysis of Levin–Lin–Chu, Im et al. [58], ADF–Fischer chi-square, and Phillips–Perron (e.g., Choi [59]). In the next step, we consider the Pedroni panel cointegration and Kao residual cointegration test to cointegrate, in the long run, between the variables used in this research. The econometric model is estimated by the panel fully modified least squares (FMOLS) and panel dynamic least squares (DOLS), and the system generalized method of moments (GMM-System). We also consider the Dumitrescu–Hurlin pairwise causality test to evaluate the causality between the variables used in this paper.

Table 1 presents the general statistics for all variables used in this research. The variables considered show little difference in their means and medians. Furthermore, the variables of tourism arrivals (LogTourism), carbon dioxide emissions ($LogCO_2$), and income per capita (LogGDP) are the higher values of Maximum.

Table 1. Description of the variables.

Variables	Mean	Median	Maximum	Minimum	Std. Dev
$LogCO_2$	4.777	4.754	5.949	3.362	0.599
LogGDP	4.361	4.399	5.005	3.726	0.238
LogREN	0.962	0.997	1.699	−1.059	0.456
LogTOURISM	6.768	6.765	7.923	5.707	0.543
LogTRADE	1.664	1.647	2.328	1.155	0.217
Observations	551	551	551	551	551

Source: The data is collected by the World Bank dataset.

Table 2 shows the correlation between the variables applied in this research. The variables of income per capita (LogGDP) and tourism arrivals (LogTourism) are positively correlated with carbon dioxide emissions ($LogCO_2$). Besides, renewable energy (LogREN) and trade openness (LogTRADE) are negatively associated with carbon dioxide emissions ($LogCO_2$).

Table 2. Correlations between variables.

Variables	$LogCO_2$	LogGDP	LogREN	LogTOURISM	LogTRADE
LogGDP	0.139	1.000			
LogREN	−0.106	−0.131	1.000		
LogTOURISM	0.833	0.277	−0.044	1.000	
LogTRADE	−0.589	0.327	−0.293	−0.579	1.000
Observations	551	551	551	551	551

Source: The data is collected by the World Bank dataset.

Table 3 presents the results of the unit root test using the arguments of Levin–Lin–Chu, Im et al., ADF–Fischer chi-square, and Phillips–Perron (e.g., Choi [59]). Therefore, the null hypothesis of the test indicates that the variables used in this study have a unit root or stationarity. According to the literature (Leitão and Balogh [43], Balsalobre-Lorente et al. [10]), we need to consider two hypotheses in the alternative, i.e., H_0: there exists a unit root test, and H_1: the variables present stationarity. The test is realized by all variables used in this research (carbon dioxide emissions, economic growth, renewable energy, tourism arrivals, and trade openness).

Table 3. Panel Unit Root Test.

Levin, Lin and Chut	**Level**	**First Difference**
$LogCO_2$	2.630	−6.355 ***
LogGDP	−5.955 ***	−6.257 ***
LogREN	1.730	−7.5593 ***
LogTOURISM	−2.044 **	−10.204 ***
LogTRADE	−2.188 **	−8.455 ***
Im, Pesaran and Shin W-stat	**Level**	**First Difference**
$LogCO_2$	3.231	−7.850 ***
LogGDP	0.820	−5.894 ***
LogREN	5.939	−7.894 ***
LogTOURISM	1.768	−9.383 ***
LogTRADE	1.211	−8.634 ***
Augment Dickey–Fuller (ADF)–Fisher Chi-square	**Level**	**First Difference**
$LogCO_2$	38.395	170.675 ***
LogGDP	42.762	128.096 ***
LogREN	18.1826	166.805 ***
LogTOURISM	49.849	193.881 ***
LogTRADE	41.337	180.323 ***
Phillips–Perron (PP)–Fisher Chi-Square	**Level**	**First Difference**
$LogCO_2$	41.163	470.443 ***
LogGDP	54.402	206.832 ***
LogREN	23.362	584.249 ***
LogTOURISM	85.511 **	293.456 ***
LogTRADE	44.669	319.133 ***

Source: The data is collected by the World Bank dataset. *** Significant at 1%, and ** 5%.

Based on the results, we observe that the variables have unit roots (not stationary) in level; however, the variables (carbon dioxide emissions, income per capita, renewable energy, tourism arrivals, and trade openness) are integrated at their first order I (1).

Pedroni panel cointegration and the Kao residual cointegration test are shown in Tables 4 and 5. Considering the results, we can infer that the variables used in this investigation are cointegrated in the long run.

Table 4. Panel Cointegration test results with intercept and trend.

(Within-Dimension)				
	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	0.417	(0.339)	−0.411	(0.659)
Panel rho-Statistic	1.029	(0.848)	0.612	(0.723)
Panel PP-Statistic	−5.361 ***	(0.000)	−6.233 ***	(0.000)
Panel ADF-Statistic	−2.372 ***	(0.008)	−2.784 ***	(0.002)
(Between-Dimension)				
	Statistic	Prob.		
Group rho-Statistic	2.502	(0.993)		
Group PP-Statistic	−8.361 ***	(0.000)		
Group ADF-Statistic	−2.789 ***	(0.002)		

Source: The data is collected by the World Bank dataset. *** Significant at 1%.

Table 5. Panel Cointegration test results with intercept and trend

	t-Statistic	Prob.
ADF	−2.172 **	(0.015)
Residual variance	0.000637	
Heteroskedasticity—and autocorrelation—consistent (HAC) variance	0.000582	

Source: The data is collected by the World Bank dataset. ** Significant at 5%.

The econometric results, with the panel's fully modified least squares (FMOLS) and panel dynamic least squares (DOLS), are presented in Table 6.

Table 6. Panel Fully Modified Least Squares (FMOLS) and Panel Dynamic Least Squares (DOLS).

Variables	FMOLS	DOLS
LogGDP	0.079 ***	0.101 ***
LogREN	−0.128 ***	−0.197 ***
LogTOURISM	−0.040 ***	−0.019
LogTRADE	−0.100 ***	−0.144 ***
R^2	0.996	0.999
Adj R^2	0.996	0.999
SE of regr	0.036	0.026
Long-run var	0.000	0.000
Mean dep var	4.77	4.813
S.D. dep var	0.597	0.565
Sum squ. resi.	0.663	0.067

Source: The data is collected by the World Bank dataset. *** Significant at 1%.

The coefficients estimated by FMOLS and DOLS are very similar, and they present the expected signs formulated by the hypotheses and the literature review. As we referred to in the methodology, we use the logarithmic form for the variables used in this paper. Thus, we can read the coefficients considering the elasticities.

The variable of income per capita (LogGDP) presents a positive effect on carbon dioxide emissions, and the variable is statistically significant at a 1% level in FMOLS and DOLS. The empirical studies of Alshehry and Belloumi [17], Balogh and Jambor [4], Dogan and Inglesi-Lotz [18], Mania [19] also found a positive effect of economic growth emissions on CO_2, showing that climate change and carbon dioxide emissions are explained by dirty industries and the use of non-renewable energy consumption. This practice stimulates CO_2 emissions and, consequently, is associated with growth activities. Nevertheless, an increase in carbon dioxide emissions also stimulates environmental damage.

Renewable energy (LogREN) is negatively correlated with CO_2 emissions. In FMOLS and DOLS estimators, a 1% level of renewable energy (LogREN) represents an improvement in climate change, i.e., the carbon dioxide emissions decreased (−0.128%), and (−0.197%), respectively. These results support the assumptions of the Directive 2009/28/EC, and the Paris Agreement (2015). Besides, the empirical studies of Acheampong et al. [25], Liu et al. [27], Bilan et al. [24] and Jebli et al. [28] also found a negative association between renewable energy and carbon dioxide emissions, mentioning that renewable energy causes a decrease in climate change and greenhouse gas.

As in previous studies (Jebli et al. [28], Katircioglu et al. [39], Leitão and Shabaz [40], Balsalobre-Lorente et al. [10]), the result obtained by tourism arrivals (LogTOURISM) presents a negative impact on CO_2 emissions. The variable is statistically significant at 1% with FMOLS, observing that the tourism sector encourages environmental improvements. This result is in accordance with the EU Agenda, the Directive 2009/28/EC, and the sustainability practices of tourism. Regarding the DOLS estimator, the variable finds the same trend, but without statistical significance.

Finally, the variable of trade (LogTRADE) presents a negative effect on CO_2 emissions, proving that international trade promotes a decrease in climate change. This result is in accordance with the hypothesis formulated.

Table 7 presents the econometric results using the GMM-System estimator without the lagged variable of carbon dioxide emissions and with the lagged variable of CO_2 emissions. The results show that the coefficients are consistent, i.e., with no second-order serial correlation in residual (e.g., Arellano and Bond test-Ar2). The results of the Sargan test showed that the instruments used are valid. According to our results, all explanatory variables are statistically significant at a 1% level.

Table 7. Generalized Method of Moments (GMM)-System Estimator.

Variables	GMM-System	GMM-System
$LogCO_{2t-1}$		0.599 ***
LogGDP	0.256 ***	0.082 ***
LogREN	−0.204 ***	−0.122 ***
LogTOURISM	−0.088 ***	−0.023 ***
LogTRADE	−0.252 ***	−0.043 ***
C	4.884 ***	1.897 ***
Observations	551	525
Ar2	0.172	0.180
Sargan	1.000	1.000

Source: The data is collected by the World Bank dataset. *** Significant at 1%.

The lagged variable of CO_2 emissions allows evaluation of the effect in the long term. The coefficient is statistically significant at a 1% level and presents a positive sign, i.e., in the long run, climate change increased (0.59%). The empirical studies of Mania [11] and Nafngiyana [20] found the same trend.

The empirical literature review, such as Özokcu and Özdemir [60], Alshehry and Belloumi [17], Och [61], and Balogh and Jambor [4], confirmed that there exists a positive relationship between economic growth and climate change. Our result has support in these studies and confirms that economic growth (LogGDP) increases carbon dioxide emissions, climate change, and greenhouse gas emissions.

As expected, the variable of renewable energy (LogREN) is negatively correlated with CO_2 emissions. The result suggests that renewable energy allows a decrease in climate change and damage to the environment. The empirical studies of Vasylieva et al. [57], Zoundi [26], and Acheampong et al. [25]

also found a negative correlation between renewable energy and CO_2 emissions. Considering a GMM-System estimator without lagged carbon dioxide emissions, Naseem and Ji [29] found a negative effect of renewable energy on CO_2 emissions (−0.1205%).

The coefficient of tourism arrivals (LogTOURISM) presents a negative impact on carbon dioxide emissions (CO_2). This result is in line with sustainable tourism, and it is supported by previous studies such as Jebli et al. [29], Balsalobre et al. [10], and Leitão and Shabaz [40].

Considering the arguments of Sun et al. [42], Roy [14], and Cole et al. [41], trade openness contributes to decreasing climate change. The variable (LogTRADE) presents a negative impact on CO_2 emissions, showing fewer pollution effects. This result is in accordance with the hypothesis of the Free Trade Area and the Monetary Optimal Zone.

Table 8 displays the causality between the variables used in this research, considering Dumitrescu–Hurlin pairwise causality test. According to the results presented in Table 8, it is possible to infer that we have a bidirectional causality between renewable energy (LogREN) and carbon dioxide emissions ($LogCO_2$). The same is valid among carbon dioxide emissions ($LogCO_2$) and trade openness (LogTRADE). In addition, there is a bidirectional causality between income per capita (LogGDP) and renewable energy (LogREN). Moreover, we observe a bidirectional causality between income per capita (LogGDP) and renewable energy (LogREN), and trade openness (LogTRADE) and renewable energy (LogREN). The variables trade openness (LogTRADE) and tourism arrivals also present a bidirectional causality between them.

Table 8. Dumitrescu–Hurlin pairwise causality test.

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
LogGDP does not homogeneously cause $LogCO_2$	6.260 ***	7.258	0.000
$LogCO_2$ does not homogeneously cause LogGDP	1.911	−0.844	0.398
LogREN does not homogeneously cause $LogCO_2$	7.047 ***	8.339	0.000
$LogCO_2$ does not homogeneously cause LogREN	4.662 ***	4.071	0.000
LogTOURISM does not homogeneously cause $LogCO_2$	5.181 ***	5.231	0.000
$LogCO_2$ does not homogeneously cause LogTOURISM	2.932	1.051	0.293
LogTRADE does not homogeneously cause $LogCO_2$	4.559 ***	4.088	0.000
$LogCO_2$ does not homogeneously cause LogTRADE	3.416 ***	1.962	0.049
LogREN does not homogeneously cause LogGDP	3.791 **	2.514	0.012
LogGDP does not homogeneously cause LogREN	6.616 ***	7.569	0.000
LogTOURISM does not homogeneously cause LogGDP	3.027	1.229	0.219
LogGDP does not homogeneously cause LogTOURISM	4.381 ***	3.744	0.000
LogTRADE does not homogeneously cause LogGDP	1.862	−0.932	0.351
LogGDP does not homogeneously cause LogTRADE	6.987 ***	8.613	0.000
LogTOURISM does not homogeneously cause LogREN	4.015 ***	2.902	0.003
LogREN does not homogeneously cause LTOURISM	4.708 ***	4.141	0.000
LogTRADE does not homogeneously cause LogREN	3.451 **	1.904	0.056
LogREN does not homogeneously cause LogTRADE	5.870 ***	6.233	0.000
LogTRADE does not homogeneously cause LogTOURISM	3.290 *	1.717	0.086
LogTOURISM does not homogeneously cause LogTRADE	4.565 **	4.086	0.000

Source: The data is collected by the World Bank dataset. *** Significant at 1%, ** 5%, and * 10%.

Furthermore, there is a unidirectional causality between income per capita (LogGDP) and carbon dioxide emissions ($LogCO_2$), among tourism arrivals (LogTOURISM) and carbon dioxide emissions ($LogCO_2$). As well, there is a unidirectional causality between income per capita (LogGDP) and tourism arrivals (LogTOURISM). Finally, we observe a unidirectional causality between income per capita (LogGDP) and international trade (LogTRADE).

Based on criteria presented by Omri et al. [62], Armeanu et al. [63], and Singh et al. [64], and considering the results reported in Table 8, it is possible infer the following conclusion. The relationship between the variables used (renewable energy, carbon dioxide emissions, trade openness, and economic growth, and tourism arrivals) does not present the neutrality hypothesis.

In this context, we can conclude that the results show a unidirectional causal relationship and a bidirectional causal relationship between the variables used in this study.

5. Conclusions

This paper considers the relationship between economic growth, renewable energy, tourism arrivals, and carbon dioxide emissions. The nexus among international trade and CO_2 emissions are also discussed in this research. The econometric strategy used panel data (panel fully modified least squares—FMOLS, panel dynamic least squares—DOLS, and GMM-System estimator) in the European Union countries (EU-28) for the period 1995–2014.

The empirical results showed that the variables considered in this study are integrated I (1) in differences based on the results of the unit root test using the arguments of Levin–Lin–Chu, Im, Pesaran, and Shin, ADF–Fischer Chi-square, and Phillips–Perron (e.g., Choi [59]). In this line, the Pedroni panel cointegration and Kao residual cointegration test demonstrated that the variables applied in this study are cointegrated in the long run.

When we consider the estimator of panel fully modified least squares—FMOLS, panel dynamic least squares—DOLS, and generalized method of moment (GMM-System), we observed that the results are similar. The econometric results with the GMM-System estimator were presented with the lagged variable of carbon dioxide emissions and without the lagged variable of CO_2 emissions. This estimator showed no serial correlation (Arellano and Bond test—Ar2), and the instruments used are valid according to the Sargan test. However, the lagged variable of CO_2 emissions presents a positive effect, showing that in the long run, climate change increases, i.e., carbon dioxide emissions are associated with pollution energies, and dirtier industries demonstrate that there are negative externalities.

Finally, we applied the Dumitrescu–Hurlin pairwise causality test to observe the unidirectional and bidirectional causality between the variables used in this research. In general, the variables used present a bidirectional causality between them, except for the relationship between economic growth and carbon dioxide emissions, which presents a unidirectional causality.

As with previous studies, such as those of Dogan and Inglesi-Lotz [18] and Mania [19], there is a positive correlation between economic growth and carbon dioxide emissions, showing that economic growth is associated with environmental damage.

The variables of renewable energy and trade openness are negatively correlated with CO_2 emissions. These results have support in the Directive 2009/28/EC and the Paris Agreement (2015), and illustrate that renewable energy and trade openness permit a decrease in climate change and greenhouse gas. The econometric results also proved a negative impact of tourism arrivals on carbon dioxide emissions, showing that the tourism sector promotes environmental improvements. This result is supported by the previous studies of Jebli et al. [38], Katircioglu et al. [39], Leitão and Shabaz [40], and Balsalobre-Lorente et al. [10].

The econometric results draw several essential conclusions in the context of the energy economy and environment. Firstly, the direct connection between economic growth and carbon emissions invites us to contemplate that the EU countries must overcome the scale effect and move towards a technological stage, where the promotion of energy efficiency and the efficient use of natural resources can lead to reducing environmental pressure. Additionally, the negative connection between emissions and trade suggests that the economic globalization processes that occurred in the EU during the last decades have allowed an inevitable environmental correction, as a consequence of more efficient transport industries. In addition, the incorporation of ICT technologies in international trade processes has made these processes more agile with a reduction in costs. Policymakers should increase their efforts to attract high tech FDI and capital compatible with the economic impulses of local economies. The inverse relationship between carbon emissions and tourism confirms that economic systems are increasingly advancing in sustainable tourism. In this respect, EU governments should promote the responsible use of resources to rank themselves competitively in international tourism markets. On the other hand, EU countries should reorient their tourism and environmental policies in the post-COVID-19 era. Since the current pandemic has revealed specific bottlenecks and deficiencies in the tourism sector, the promotion of a sustainable tourism sector is positioned as a fundamental instrument to achieve the objective of sustainable economic growth.

Finally, the negative connection between the promotion of renewable sources and carbon emissions confirms the need for EU policymakers to promote energy efficiency and renewable sources within the energy mix, in order to reach COP21 agreements. These measures will diminish the technological gap between the most advanced economic systems and those that are still in a stage where the economic growth is harmful to the environment.

Based on the results presented, it is possible to refer to the same implications for future work, as well as some recommendations for economic policy. In terms of theoretical and empirical implications, we note that the results presented in this study are in accordance with the EU's standard energy policy. Moreover, in this study, we stress that it will be necessary to continue using sustainability practices of tourism and cleaner energy, allowing a reduction in climate change and damage to the environment, as well as greenhouse effects and global warming. In terms of future studies, we think it will be interesting to extend the group of countries, namely to the BRICs (Brazil, Russia, India, and China), and Central and Eastern Europe (e.g., Jambor and Leitão [65], and Pilatowska and Wlodarczyk [66]) using a different econometric strategy such as the panel ARDL model, specifically the pooled mean group (e.g., Pesaran et al. [67], Bildiric [68], Sulaiman and Rahim [69] and Mensah et al. [70]). It will be difficult to predict whether the pandemic crisis will have a very high impact on the international economy. However, one thing has already been noticed; China is currently dominating international trade. In this context, it is witnessing a reversal of the logic of globalization and dominant countries throughout the 1980s and 1990s, namely the United States of America, European Union countries, and ASEAN countries. However, it will be essential to remember that the international community overcame several economic and financial crises, such as the oil crisis of the 1970s, the economic crisis of 1929, and the crisis of 2008–2009 (subprime). The good news that comes to us from the media is that the Coronavirus has been allowing the reduction in carbon dioxide emissions and the improvement of ecosystems in general. Though economic growth has been slowing down, we believe that from this stage onwards, there will be an increasing reorganization of human ecology and sustainable development. It will be necessary that the data that will be published in the coming years by such institutions as the World Bank and the World Health Organization will allow us to reach meaningful conclusions and life lessons for the near future.

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