Journal of Cleaner Production 305 (2021) 127117

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Environmental consequences of economic complexities in the EU amidst a booming tourism industry: Accounting for the role of brexit and other crisis events

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A R T I C L E I N F O

Article history:
Received 31 January 2021
Received in revised form
27 March 2021
Accepted 12 April 2021
Available online 20 April 2021

Handling editor: Mingzhou Jin

Keywords:
Economic complexity index
Brexit
Greece Bailout crisis
CO_2 emissions
Environmental sustainability
Energy consumption
Carbon-reduction
Economic growth

A B S T R A C T

The European Union (EU) is one of the strongest, but most complex unions in the world with a competitive tourism industry. The aim of this study, therefore, is to account for economic complexity index (ECI), Brexit and other crisis episodes in the growth-energy-emissions nexus. Theoretically, the traditional Environmental Kuznets Curve (EKC) model is assessed by adopting a One-step System Generalized Method of Moment (Sys GMM) on data for 26 EU member states over the period from 1995 to 2018. For the first time, an EU-macro regional analysis is conducted with and without the UK. Empirical results reveal that an increase in tourism, real GDP per capita, and energy use across the four EU macro regions leads to increase in carbon emission. In some regions, it was observed that tourism, ECI, Brexit, and the Greece bailout have no significant impact on carbon emission. This suggests that the increase in international travel, complexity of the economy, and financial crisis do not accelerate environmental crisis in such regions. However, where such factors are statistically significant, Brexit and the Greece bailout crisis both heighten emissions. Particularly, when the UK is excluded, Brexit and the Greece bailout crisis increase and reduce emissions, respectively. The EKC hypothesis, however, holds in either scenario. Based on these empirical findings, vital policy directions are suggested for a post-Brexit EU-UK energy and environmental relations.

1. Introduction

The goal of achieving economic growth and stabilizing energy demand due to environmental concerns simultaneously has been the subject of much discussion among scholars. This aim is seen as achieving two tasks that are divergent to one another, as energy demand and consumption are twin factors for spurring economic growth. Subsequently, environmental concerns have risen as more and more damage has bedeviled the environment, causing climate change and ecological destruction. The emission of Chlorofluorocarbons (CFCs) and greenhouse gases are chief in this regard, and as such, measures have been taken to either reduce the level of emissions or seek environment-friendly sources of energy. According to Dogan et al. (2020), sustainable development is at the forefront of national development plans worldwide, and curbing emissions is key to bringing such objective to fruition, as epitomized by the consensus reached at the 21st COP (Conference of the Parties) meeting in Paris, 2015.

The Environmental Kuznets Curve (EKC) was developed to describe a country's pathway along the lines of economic growth

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https://doi.org/10.1016/j.jclepro.2021.127117
0959-6526/

and development and the subsequent environmental degradation that ensues from such. Along the early stages of economic development, what Can et al. (2019) tag as "economic expansion" takes precedence over environmental concerns, leading to economic growth and development at the expense of a healthy environment. This early stage is characterized by economic concerns taking center stage for policy makers and the government. In the view of Dong et al. (2020), countries at this stage are more preoccupied with industries like fertilizers and petrochemicals. Gozgor and Can (2016) also attempted to provide an explanation for this phenomenon, claiming job creation and increasing output levels are paramount for decision-makers. This continues till a threshold level of income is attained, and then concerns switch to environmental preservation and protection, with more attention drawn toward stimulating environmental protection. The EKC, therefore, arises out of a conscious effort of decision-makers (Gozgor and Can, 2016; Shahbaz et al., 2017). This process is affected by a number of factors, goods basket and the rate of industrialization and technique of production. Sophisticated measures of production are likely to have a less detrimental effect on the environment, especially when allied with a high level of knowledge and skill in production. This tripartite cocktail of knowledge, skill and sophistication in production has been labeled economic complexities (Can and Gozgor, 2017), which refers to a measure of the level of sophistication and technology employed in the manufacturing process (Dogan, Saboori and Can, 2019).

The discourse surrounding emissions and environmental degradation has revolved around various economic variables and activities. It has been examined in tandem with causality effects with economic growth, trade openness, financial development, environmental sustainability, energy demand and tourism (Malik2016; Ahmad et al., 2018; Salahuddin et al., 2018; Shaheen et al., 2019; Chishti et al., 2020; Baloch et al., 2021). Tourism in particular has vast economic effects, ranging from job creation, earning foreign exchange, linkage effects with other industries and raising national income. The industry is regarded as one of the top service industries worldwide, raking in millions of dollars for nations annually. Such an industry with significant effects would understandably leave imprints on the environment. Conversely, its effects of the environment cannot be left out. According to Malik et al. (2016), despite tourism being a definite source of income for economies, it contributes to natural destruction, and, as such, sustainable tourism and sustainable development are often mentioned in the same breath.

The level of a country's sustainable growth, human capital, institutional quality and innovation expertise constitutes its degree of economic complexity (Dogan et al., 2020), which goes a long way in determination of its product and service delivery. The more technological advancement, refinement and sophistication adopted in production of a good, the less damaging it is on the environment. Tourism, when carried out in countries with a high level of economic complexity, should arguably be less destructive on the environment. Dogan et al. (2019) aim to provide a justification for this, pointing at the fact that MDCs are at the latter parts of the EKC, making environmental and health concerns a critical consideration when embarking on any economic activity. In addition, economic complexities are expected to move along the lines of the EKC, which translates to less damaging environmental outcomes attained due to more refined technological production processes. This is corroborated by the claim of Malik et al. (2016) that developing more complex industries is a potential way to reduce the level of fossil fuel consumption and mitigate climatic damage.

However, the link between economic complexities and tourism in the context of emissions and environmental consequences has not been well considered in the literature. Shaheen et al. (2019) regard the EU as the most competitive in terms of travel and tourism competitiveness, with an influx of over 620 million tourists. Furthermore, from 1990 to 2008, the region witnessed a 6% average yearly growth of CO_2 emissions generated from fossil fuels, with a significant portion attributed to air transport. Air transport is vital to tourism, and a higher influx of tourists translates to more pollution due to more flights. This study finds peculiarity in this regard as it aims to examine the effect of economic complexities would have on the tourism-emissions linkage. Given the EU is one of the most preferred destinations of myriad tourists, it becomes essential to examine the effect of economic complexities in the European tourism industry. The novelties of this study are due to the essence that (1) it adds new putative findings to the existing literatures; (2) This is the only paper that groups the post-Brexit nations in five regions; (3) the findings from this study will allow environmental conservation or concerned policy makers to establish rigid informed decisions for each region, thereby reducing the workload on policy directions for the whole EU simultaneously. The next section gives insight into existing literature. Data and variable used are presented in section three, while estimations and results are discussed in section four. Section five concludes the study with vital policy implications and recommendations.

2. Literature review

2.1. Economic complexity index and environment nexus

The size and development of an economy are key ingredients to determining the relationship between the summary of exports-imports and the GDP alongside the growth rate. Other factors seen to be playing an important role include large pool of investment and the superiority of the economic frameworks and structures. However, the ability of nations as regard technology's product and economy development of such nations is termed economic complexity. The Economic Complexity Index (ECI) is a comprehensive proportion of the beneficial abilities of huge financial frameworks, generally urban communities, districts, or nations. Specifically, the ECI hopes to clarify the information gathered in a populace and that is communicated in the financial exercises present in a country. In particular, complexities of economy insinuate beneficial structure of a country, which prompts a specific construction of energy use and, as a result, a specific effect on the environment. Certainly, the carbon emission of a country could be influenced from the country's productive stricture as a result of the economy complexity level of the products, which has undesirable impact on the environment through pollution discharge. However, the ECI also digs in information and capacities, developments and exploration, which can help with fortifying greener items and amicable progression in the climate. As result of this environmental context, different analysts have thought about the nexus between environmental consequences and various proxies for ECI. To examine the influence of emission targeted policy on industrial activities, with a specific attention to economic complexity, Dong et al. (2020) employed a QARDL approach between 1978 and 2017. Major findings of the research showed that improved productivity of goods and services drives environmental degradation, and, on the other hand, the presence of Environmental Kuznets Curve is also validated.

With relation to how countries around the world adapt to the environmental regulations, Mealy and Teytelboym (2020) examined ways by which countries reposition their existing sectors and industries to be more effective and eco-friendlier. The study found that more developed countries have more adaptable measures, reduced greenhouse gas emissions and effective greening and eco strategies after controlling per capita GDP. Can and Gozgor (2017) assessed the impact of the economic complexity, which is seen to be the determination for the structure and scale on greenhouse emissions with greater focus on the EKC hypothesis. Utilizing the unit root test, the research results revealed a confirmation of the hypothesis for the case of France. Second, the existence of a relation between energy usage on carbon dioxide emissions was found. And lastly, that a reduction in CO_2 emissions in the long run is majorly triggered by economic complexity. A similar paper which examined the nexus between a country's diversity of exports, its energy consumption and the environment was carried out by Shahzad et al. (2021). In the study methodology, unit root test and the quantile autoregressive distributed lag (QARDL) were employed. The objective of the research arrived at findings which gave support to the nexus between fossil fuel energy and economic complexity in enhancing environmental effects in the United States.

A study carried out in Turkey by Gozgor and Can (2016) examined the relations between an improved productivity, energy consumption and export product diversification on emissions between 1971 and 2010. Findings from the paper also confirmed the EKC hypothesis for the case of Turkey in both short run and long run within the scope of the study. Neagu (2019) set out to verify the nexus between complexity index and CO_2 emissions for 25 European Union countries between 1995 and 2017. Using a panel cointegration test, the results of the research not only showed that economic complexity must be taken into consideration, but also found a long-run dependency between the two variables (economic complexity and CO_2 emissions) under consideration, which was envisaged by an inverted U-shaped curve. With relation to the cause and effect of energy usage and consumption, it was observed that by increasing energy consumption by 10%, a 3.9% rise in CO_2 emissions will occur.

To explore the relationship that exists between the environment and economic policy indicators, Sarkodie et al. (2019) employed an Autoregressive-Distributed Lag (ARDL) which paved the way to the major findings of the research that a correlation between food and impacts of the people on the environment exists. Can, Dogan, and Saboori (2020) investigated the influence of export diversification on carbon emissions for developing countries in the context of a new approach for EKC. Using autoregressive distributed lag bounds test, the fully modified ordinary least, dynamic ordinary least squares, and squares, the validity of the EKC hypothesis was ascertained for the developing economies under study. It was also noted that an enhanced productivity contributes as a major element in raising emission figures in the selected countries.

2.2. Energy use, international travel and the environment

The energy-environment nexus has received considerable attention in the literature across many climes, especially in this 21st century. Globalization, which is recognized as a key ingredient for interconnectedness in this present century, has both its pros and cons. Similarly, tourism has both its good and bad sides which transcend economic or social issues to environmental factors. The same way it has enabled the development of many economies, it has seen the 'natural destruction' of others (EU, 2011).

The tourism industry is experiencing bourgeoning figures in terms of international travel across many countries. Studying the interrelations between environment, tourism, energy, and economic growth, Shaheen et al. (2019) examined the relationship between international tourism, demand for energy, CO_2 emissions, and economic growth by utilizing 10 tourism inclined countries. Employing panel data, findings from the research confirmed the Environmental Kuznets Curve hypothesis in the panel of the top 10 countries and that economic growth and trade openness both cause an increase in tourism income.

Similarly, a study by Malik et al. (2016) examined the long-term relationship between international tourists' arrival, deterioration of the environment, and specific growth elements within the purview of Austria between 1975 and 2015 and revealed that influx of tourists, increased population and the average income had an effect on the environment, while the rise in the population was responsible for the impact felt on food production in this clime.

In China, a closely related study by Sharif et al. (2020) assessed the effect of three variables (i.e., economic growth, tourism, and globalization) on CO_2 emissions, and GHG emissions in general. The study employed the QARDL approach, which indicated that economic growth drives environmental degradation, and, on the other hand, validating the presence of Environmental Kuznets Curve. Similarly, Leal, Marques, and Fuinhas (2019) examined the detachment of economic growth from greenhouse emissions of the Australian economy with attention on sectors including the construction sector, agriculture, industrial, etc., and also tested the efficacy of these sectors. The study used the decoupling model combined with the Logarithmic Mean Divisia Index (LMDI) which revealed that the Australian economy has started to invigorate its sectors, which has, in turn, led to the reduction of the total GHG emissions simply as a result of the efficacy of these sectors.

From a larger viewpoint and perspective, Al-Mulali et al. (2015) assessed and tested for the EKC hypothesis for 93 countries, by grouping them by their level of income due to the changing ecological mark between these climes. Employing a panel data analysis, findings from the paper revealed an invalidity of the EKC hypothesis for low-and middle-income countries simply because the countries are still at a premature stage of development. For the upper- and middle-income climes, results from the study confirmed the validity of EKC hypothesis. Khan, Yu Belhadi, and Mardani (2020), in a study on the effects of naturally generated energy on international trade and environmental quality for Nordic counties from 2001 to 2018, found that renewable energy strongly and positively associated with international trade in Northern Europe countries. It also revealed that naturally generated energy and its usage has a positive impact on the quality of the ecology.

Much research has been carried out on the impact of energy usage on the emissions and the environmental quality at large, such as that by Sharma (2011) which examined the major triggers of CO_2 emissions for a total number of 69 countries, and for three category income-based panels, which included the high income, middle income and low-income panels. From the Panel GMM model, it was observed that an increase in the productivity raises carbon dioxide emissions in low- and middle-income economies while energy usage has a long-term relation with CO_2 emissions for high-income countries.

Similarly, Marrero (2010), whose study analyzed a panel dynamic model for European Union 27 members relating GHG emissions with real GDP and the total energy consumption, discovered that energy use and improved productivity have a positive effect on CO_2 emission in the models adopted. In the same vein, Hamit-Haggar (2012) assessed the long-term relations between GHG emissions, energy use and economic growth for Canadian industrial sectors. Energy consumption, GDP growth and CO_2 emission were found to be co-integrated and also that energy consumption and GDP growth have a long-run effect on CO_2 emission. Becken and Patterson (2009) measured the usage of fossil fuels (CO_2 emission) in New Zealand toward obtaining sustainable tourism and revealed that energy used for tourism has a great impact in contributing to CO_2 emission in the country.

To assess the association of CO_2 emission and the usage of energy with aggregate output using a panel VEC model for six countries in Central America, Apergis and Payne (2009) found that the consumption of energy has a positive and substantial effect on emissions while real output shows a quadratic association. The findings from the research gave meaning to the bourgeoning numbers of emissions alongside the EKC hypothesis and output, which stabilized at some point before diminishing.

Another study which focused on the type of relations that existed between the usage of energy, the CO_2 emission and output at large was carried out by Ang (2007) in France between 1960 and 2000. The research discovered the same pattern in energy consumption thereby translating to a carbon dioxide emission, also revealing a long-run relation between general output and CO_2 emissions.

In a paper that focused on emerging economies and the influence of increased productivity, impacts of humans on the environment, their consumption of energy, and urbanization carried out by Danish and Wang (2019), it found that a population transition from rural to urban areas raises the ecological footprint, while a controlling impact of economic growth and urbanization will go a long way to mitigating the impact of humans on the environment, thereby preventing a biodiversity loss.

Regarding the establishment of linkage between energy use and environment, a research conducted by Ozcan et al. (2018) on whether the EKC hypothesis is valid in Turkey provided several findings. First, that there exists a nexus between improved productivity and human impacts in the country. Furthermore, that the influence of economic growth on environmental depletion is positive and exhibited a slow rising trend in all the periods under study. This implies that the EKC hypothesis for the Turkish economy is not confirmed. This is akin to what Wang et al. (2013) discovered on the assessment of the incorporation of spatial econometric techniques in estimating EKC for ecological footprint. The results of the study give no support to the evidence of an inverted U-shape Environmental Kuznets Curve.

3. Data and methods

3.1. Data and variables

This study examined the relationship between carbon emission and real GDP per capita, tourism, energy consumptions, economic complexities, and global financial crisis by using a panel data from the post-Brexit countries – EU countries after the exit of the UK on January 31, 2020. The countries and corresponding data are listed below:

1. Adriatic-Ionian (Croatia, Greece, Italy, Slovenia)
2. Alpine (Austria, France, Germany, Slovenia)
3. Baltic Sea (Denmark, Estonia, Finland, Latvia, Lithuania, Poland, Sweden)
4. Danube (Bulgaria, Czech Republic, Slovak Republic, Romania)
5. Others (Spain, Belgium, Cyprus, Ireland, the UK, Portugal)

Variables' description.

The dependent and the independent variables employed in this study are listed along with their source as shown in Table 1.

3.2. Model and methods

To examine the environmental consequence of carbon emission using evidence of panel data series from BREXI countries, this study incorporates techniques to analyze the model with longitudinal/panel data; that is, pooled Ordinary Least Squares (pooled-OLS) or Least Squares Dummy Variable (LSDV) regression estimation, Fixed effect estimation (FE), Random effect estimation (RE) and one-step Generalized Method of Moment (GMM) estimation for controlling for heteroscedasticity, serial correlation and endogeneity assumption. Panel/longitudinal data, as posited by Kennedy (2008), have observation on the same units or entities in several different time periods. There are multiple entities (e.g., individual, firm, state, countries, etc.) in panel data, each of which has repeated measurement at different time periods (e.g., days, weeks, months, quarters, and years).

Panel data model may be static or dynamic. Static panel data regressions as defined by Baltagi (2008) and Cameron and Trivedi (2009) allow the individual study behavior in a repetitive environment. If $\mathrm{Y_{it}}$ is our variable of interest (i.e., dependent variable), then static panel data models are described by

$$\mathrm{Y_{it}} = \mathrm{X_{it}}\beta_\mathrm{i} + \alpha_\mathrm{i} + \mathrm{V_{it}}(1)$$

$$\mathrm{i} = 1, \ldots, \mathrm{N(individuals)}$$

$$\mathrm{t} = 1, \ldots, \mathrm{T(time)}$$

where:

Y_{it} is dependent variable of individual i in time t, $X_{it}$is the it-th observation on k explanatory variables, β_i is the parameter vector, α_i denotes the unobserved individual-specific time-invariant effects, and the residual disturbance term V_{it} has zero mean, constant variance, and is uncorrelated across time and individuals. Depending on the nature of α_i, static model can be grouped into Fixed and Random Effect Model. Fixed effect model assumes that α_i are individual fixed parameter that may or may not influence the predictor variables while random effect model assumes that α_i are random variables uncorrelated with the explanatory or predictor variables included in the model (Oscar, 2007). Unlike the fixed effect model, the random effects model assumes the variation across entities to be random and the crucial distinction between the random and fixed effects models is whether the unobserved entity effect embodies elements that are correlated with the regressors in the model, not whether these effects are stochastic or not (Green, 2008, p.183).

Hausman test can be used to decide if a model is a fixed or random effects model. The null hypothesis is that the favored model is random effects (Green, 2008). It fundamentally tests whether the specific errors are connected with the regressors. If the test is significant ($p < 0.05$), the invalid theory of no connection between the specific errors will be dismissed, and, hence, the fixed effects model will be supported. Also, the descriptive statistics of the variables used, the pairwise correlation matrix, and the bin

Table 1
Description of variables.

Variables	Acronym	Data source
Carbon dioxide emission (Million tonnes of carbon dioxide)	CO_2	British Petroleum
GDP per capita (constant 2010 US$)	RGDP	World Bank Database
Primary energy consumption (Million tonnes oil equivalent)	ENC	
International tourist arrivals	TOUR	World Bank Database
Economic Complexity Index	ECI	The ATLAS of Economic Complexities
Dummy Variables for post-Brexit countries	DBREXIT	Author
Degree of global financial crisis	DGREECEGFC	Author

scatter plot of this variable are presented. The panel data were first run with pooled-OLS, then it was proceeded to apply the static model, and choose between fixed effect and random effect model using Hausman test. Then, to control for endogeneity of the explanatory variables, serial correlation and heteroscedasticity, this study employed Generalized Method of Moments, GMM – one step methodology.

4. Results and discussions

4.1. Pre-estimation diagnostics

Table 2 below reveals the total number of observation (624) and the descriptive statistics of log of the explanatory and the potential explained variables in this study. It can be observed from the table that the average mean of carbon dioxide is 42.7% within the maximum and minimum value of 19.1% and 68.1% with standard deviation of 1.2, which indicates that there is less disparity among the observations and its mean. On average, the mean of real GPD is 10.04 within the range value 8.24 and 11.24 with deviation value of 0.69, which is a good measure because of its low level of disparity. Regarding the real GDP squared, its mean is 101.36 with standard deviation of 13.61, indicating large disparity between among the observations and their mean; it has minimum and maximum value of 67.87 and 126.50, respectively. Moreover, the mean of tourism engagement is 15.80; it has standard deviation of 1.20; minimum value of 13.14, and maximum value of 18.30. Furthermore, on average, the average energy consumed in post-Brexit countries is 34.4% within the minimum and maximum consumption of 77.4% and 58.6%. The small deviation of each energy consumed from their mean is 12.9%.

Table 3 shows the pairwise correlation between the explanatory variables and the explained variables (CO_2). All the explanatory variables, excluding the dummy variables for post-Brexit countries and global financial crisis, are significantly related to CO_2 emission. This means that there is positive relationship between these variables and carbon emission. Also, there is the strongest relationship between the energy consumption and CO_2 emission, indicating that increased in the use of energy leads to increase in the CO_2 emitted to the environment.

Furthermore, in order to lay more emphasis on the CO_2 emission and independent variables nexus, this study employed bin scatter plot, which shows the movement of the selected independent variables and the dependent variables to the fitted line (Cattaneo et al., 2019). The bin scatter plot measures the precision of slope estimate and low standard error with the datapoints fitted to the regression line. Conversely, if the bin datapoints are largely deviated from the regression line, then the slope estimates are not precise, thus indicating large standard error (Stepner, 2014). Fig. 1 indicates the log linear relationship between CO_2 and real GDP per capita. It buttresses more explanation on the weak positive correlation value of 0.37 between the two variables. This means that CO_2 also increases as real GDP per capita increases, but, since the relationship is weak, the datapoints are dispersed from the regression line. Fig. 2 depicts the scatter plot of log linear relationship between tourism and CO_2 emission. It explains more about

Table 2
Descriptive statistics of the studied variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
LCO_2 emission	624	4.272928	1.269165	1.908481	6.81405
LRGDP	624	10.04401	0.6908181	8.238591	11.24717
LRGDP2	624	101.3586	13.61919	67.87438	126.4988
LTOUR	624	15.80122	1.19833	13.1402	18.30776
LENC	624	3.442711	1.293313	0.7744725	5.856475

the strong positive correlation values of 0.79 between these variables. This means that increase in tourism-led activities contributes to increase in CO_2 emission of post-Brexit countries. The strong relationship shows the fitness of the datapoints to the regression line. For CO_2 and energy consumption, Fig. 3 shows positive relationship between them. This explains the high correlated value of 0.98%, indicating the reasons why the datapoints are mostly fitted to the regression line.

Furthermore, on the relationship between the CO_2 and economic complexities index, the bin scatter plot shown in Fig. 4 indicates that both variables are increasing at the same time and rate, but the datapoints are largely deviated from the regression line, indicating that the relationship is weak. Generally, the four plots indicate that the regression estimates showing the relationship between real GDP per capita, and economies complexities are not precise, while that of tourism activities and energy consumption are more precise with low standard error of estimates.

Data gathered were categorized under five EU macro regions, and comparative analysis was assessed using three models (Table 4 and Table 5), which are Pooled OLS (LSDV), Fixed Effect (FE) model and Random Effect (RE) model. Then, Hausman test, which examined the best model for panel data between the FE and RE, was employed. Hausman test is a test of no fixed effect in the null hypothesis. If the hypothesis fails to reject at 5% level of significance, then the best model is RE otherwise it is FE if the hypothesis is rejected in favor of the alternative hypothesis. Stepping forward, for all the EU countries and post-Brexit countries (after the exit of the UK in 2020), the aforementioned three techniques were separately compared (Table 6 and Table 7) with generalized method of moment (GMM).

For countries in the Adriatic-Ionia region (Croatia, Greece, Italy, Slovenia), the result for Adriatic-Ionia samples (Table 4 column 2 and Table 5 columns 2 and 6) show the significant value of LRGDP in pooled-OLS, FE, and RE model. This variable has the coefficient of 6.43 for both pooled-OLS and RE model, and 5.05 for FE. This denotes that a unit percent increase in real GDP per capita will increase carbon emission by 6.43% and 5.05% in the Adriatic-Ionia region. Furthermore, all the explanatory variables under pooled-OLS and RE model either have significant negative or positive (1% or 10% level) relationship with carbon emission. For instance, tourism has negative but significant impact on CO_2 with coefficient of −0.091, which indicates that a unit increase in tourism activities of the Adriatic-Ionia region will decrease CO_2 emission by 0.09%. As for FE, some of the variables, such as economic complexities, tourism, and degree of global financial crisis, have no significant effects on the CO_2 emission.

For countries in the Alpine (Austria, France, Germany, Slovenia) region (Table 4 column 3 and Table 5 columns 3 and 7), it shows the significant value of LRGDP in pooled-OLS, and FE, but insignificant in RE. For the significant ones, this variable has the coefficient of −3.94 and −3.36 for pooled-OLS and FE model, respectively. This denotes that a unit percent increase in real GDP per capita will decrease carbon emission by 3.94% and 3.36%, respectively, in the Alpine region. Furthermore, all the explanatory variables under pooled-OLS model either have significant negative or positive (1%, 5% or 10% level) relationship with carbon emission. For instance, tourist activities have negative but significant impact on CO_2 with coefficient pf −0.182, which indicates that a unit increase in tourism activities of the Adriatic-Ionia region will decrease the CO_2 emission by 0.182%. As for FE, all the variables except economic complexities (ECI), and tourism have no significant effects on the CO_2 emission. Contrary to the FE estimation, ECI, tourism, and energy consumption have significant impact on carbon emission. In fact, 1% increase in tourism under this model will also decrease the CO_2 emission by 0.182%.

Table 3
Correlation matrix analysis.

	LCO_2	LRGDP	LRGDP2	LTOUR	LENC	ECI	DBREXIT	DGREECEGFC
LCO_2	1							
LRGDP	0.3672*	1						
	0.0000							
LRGDP2	0.3702*	0.9994*	1					
	0.0000	0.0000						
LTOUR	0.7931*	0.4287*	0.4278*	1				
	0.0000	0.0000	0.0000					
LENC	0.9793*	0.4101*	0.4142*	0.7960*	1			
	0.0000	0.0000	0.0000	0.0000				
ECI	0.4762*	0.5840*	0.5839*	0.2971*	0.5402*	1		
	0.0000	0.0000	0.0000	0.0000	0.0000			
DBREXIT	−0.0372	0.1214*	0.1200*	0.1626*	−0.0109	0.0013	1	
	0.3539	0.0024	0.0027	0.0000	0.7858	0.9745		
DGREECEGFC	0.0057	0.0808*	0.0787*	0.0482	0.0088	0.0105	−0.2582*	1
	0.8873	0.0435	0.0495	0.2289	0.8261	0.7944	0.0000	

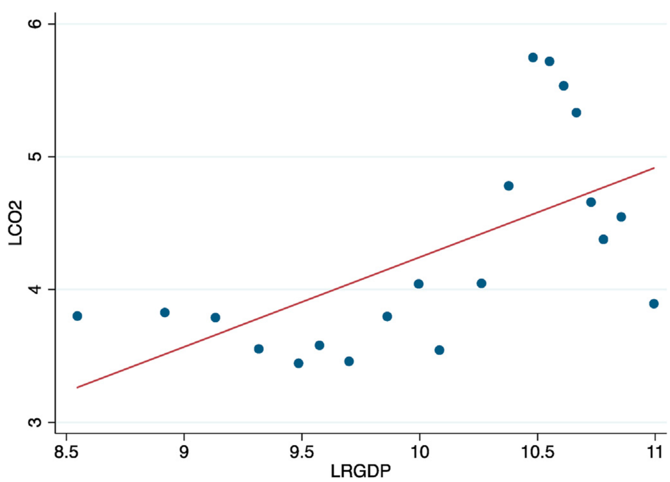

Fig. 1. Bin scatter plot for CO_2 and real GDP per capita.

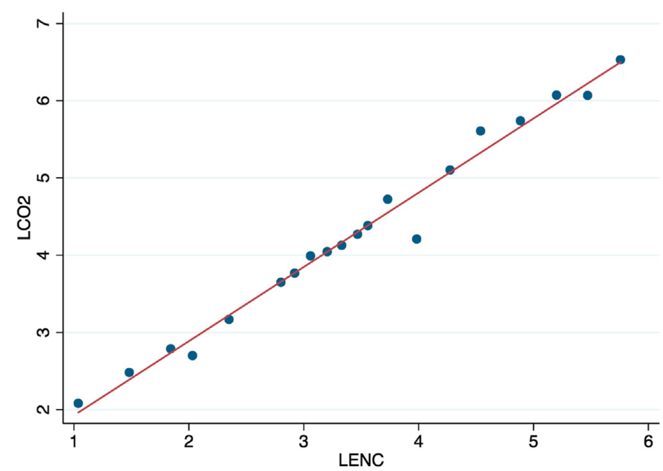

Fig. 3. Bin scatter plot for CO_2 and energy consumption.

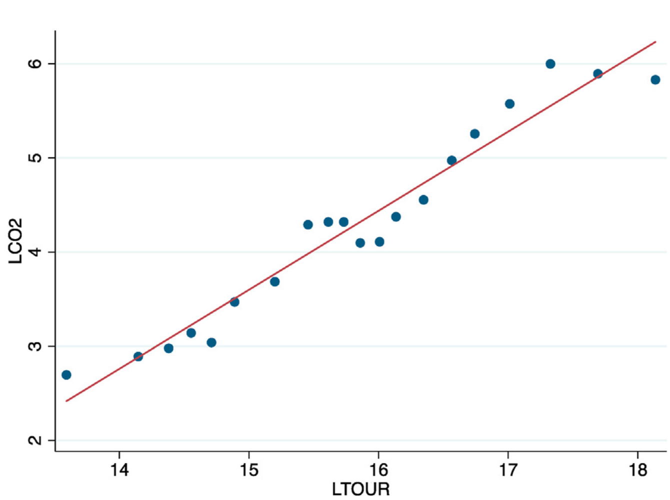

Fig. 2. Bin scatter plot for CO_2 and tourism.

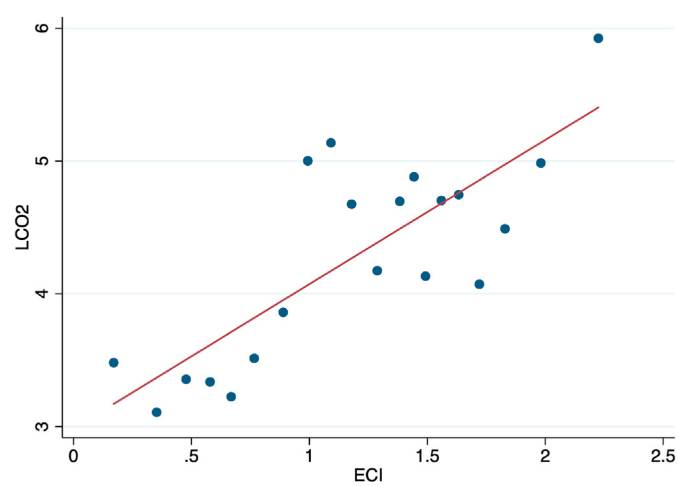

Fig. 4. Bin scatter plot for CO_2 and real economic complexities.

Furthermore, for countries in the Baltic Sea region (Denmark, Estonia, Finland, Latvia, Lithuania, Poland, Sweden), the result for the samples (Table 4 column 4 and Table 5 columns 4 and 8) show the significant value of LRGDP in pooled-OLS, FE, and RE models. This variable has the coefficient of 8.90, −4.06, and −3.44 pooled-OLS, FE, and RE, respectively. This denotes that a unit percent increase in real GDP per capita will increase carbon emission by 8.90% for under pooled-OLS. The relationships between real GDP per capita and CO_2 under FE and RE are negative, which means that a unit increase in this variable will decrease CO_2 emission by 4.06% and 3.44%, respectively. Furthermore, all the explanatory variables except tourism for FE and RE have significant negative or positive (1%, 5% or 10% level) relationship with carbon emission.

Table 4
Pooled OLS (or LSDV) for comparative analysis across the EU macro regions.

VARIABLES	Adriatic-Ionian	Alpine	Baltic Sea	Danube	Others
LRGDP	6.431***	−3.194***	8.904***	−0.875**	−0.601
	(0.862)	(1.056)	(1.581)	(0.384)	(0.559)
LRGDP2	−0.313***	0.164***	−0.443***	0.0644***	0.0367
	(0.0447)	(0.0492)	(0.0762)	(0.0214)	(0.0276)
LTOUR	−0.0913***	−0.182***	0.392***	0.257***	0.0650***
	(0.0226)	(0.0254)	(0.0697)	(0.0164)	(0.0126)
LENC	1.066***	1.054***	0.782***	0.821***	0.890***
	(0.0246)	(0.0135)	(0.0844)	(0.0292)	(0.00847)
ECI	−0.202***	0.428***	−0.351*	−0.150***	0.00165
	(0.0126)	(0.0489)	(0.200)	(0.0532)	(0.0128)
DBREXIT	−0.144***	0.0564*	−0.928***	−0.643***	−0.200***
	(0.0351)	(0.0313)	(0.202)	(0.0608)	(0.0361)
DGREECEGFC	−0.0633**	0.0997**	−0.687***	−0.435***	−0.155***
	(0.0243)	(0.0426)	(0.210)	(0.0548)	(0.0388)
Constant	−30.48***	18.07***	−47.96***	0.602	2.639
	(3.962)	(5.391)	(7.757)	(1.756)	(2.733)
Time-specific effects	Yes	Yes	Yes	Yes	Yes
Observations	72	96	168	96	192
R-squared	1.000	0.999	0.941	0.994	0.997

Robust standard errors in parentheses *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 5
Fixed and random effects estimates for comparative analysis across the EU-macro regions (Dep. Variable: LCO_2, log).

	Fixed Effects Estimation					Random Effects Estimation				
VARIABLES	Adriatic-Ionian	Alpine	Baltic Sea	Danube	Others	Adriatic-Ionian	Alpine	Baltic Sea	Danube	Others
	LCO_2	LCO_2	LCO_2	LCO_2	LCO_2	LCO_2	LCO_2	LCO_2	LCO_2	LCO_2
LRGDP	5.047**	−3.362***	−4.026***	1.138**	0.583	6.431***	−3.194	−3.443***	−0.875***	0.720
	(0.876)	(0.474)	(0.450)	(0.215)	(1.293)	(1.248)	(2.216)	(0.626)	(0.306)	(0.956)
LRGDP2	−0.243**	0.178**	0.235***	−0.0577**	−0.0296	−0.313***	0.164	0.200***	0.0644***	−0.0347
	(0.0491)	(0.0331)	(0.0276)	(0.0166)	(0.0589)	(0.0658)	(0.103)	(0.0371)	(0.0188)	(0.0447)
LTOUR	−0.0687	0.0215	−0.00281	−0.0142	−0.0445	−0.0913***	−0.182***	−0.00168	0.257***	−0.0489
	(0.0246)	(0.0381)	(0.0213)	(0.0352)	(0.0417)	(0.0234)	(0.0531)	(0.0269)	(0.00712)	(0.0392)
LENC	0.624**	0.889***	0.514***	0.960***	1.010***	1.066***	1.054***	0.535***	0.821***	0.982***
	(0.135)	(0.0959)	(0.122)	(0.126)	(0.0608)	(0.0358)	(0.0272)	(0.133)	(0.0196)	(0.0181)
ECI	−0.0750	0.0262	0.381***	−0.206***	−0.0197	−0.202***	0.428***	0.385***	−0.150***	−0.0221
	(0.0527)	(0.0296)	(0.0602)	(0.0344)	(0.0413)	(0.00972)	(0.108)	(0.0598)	(0.0541)	(0.0355)
DBREXIT	−0.139*	−0.261**	−0.521***	−0.173	−0.0905	−0.144**	0.0564	−0.459***	−0.643***	−0.0972
	(0.0379)	(0.0794)	(0.0990)	(0.103)	(0.0684)	(0.0577)	(0.0531)	(0.0981)	(0.0453)	(0.0673)
DGREECEGFC	−0.0514	−0.176*	−0.373***	−0.125	−0.0638	−0.0633***	0.0997	−0.328***	−0.435***	−0.0684*
	(0.0199)	(0.0682)	(0.0737)	(0.0870)	(0.0398)	(0.00744)	(0.0719)	(0.0735)	(0.0584)	(0.0375)
Constant	−22.64**	16.51***	18.70***	−4.016*	−1.222	−30.48***	18.07	16.25***	0.602	−1.922
	(4.032)	(1.875)	(1.984)	(1.401)	(6.630)	(5.649)	(11.36)	(2.852)	(1.319)	(4.748)
Time-specific effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	72	96	168	96	192	72	96	168	96	192
R-squared	0.982	0.912	0.898	0.960	0.898					
Number of country ID	3	4	7	4	8	3	4	7	4	8

Robust standard errors in parentheses *** p < 0.01, ** p < 0.05, * p < 0.1.

Additionally, for countries in the Danube region (Bulgaria, Czech Republic, Slovak Republic, Romania) (Table 4 column 5 and Table 5 columns 5 and 8), all the explanatory variables under pooled-OLS and RE model either have significant negative or positive (1%, 5% or 10% level) relationship with carbon emission. For instance, real GDP per capita and tourist activities have negative and positive impact on CO_2 with the same coefficients of −0.875 and 0.257, respectively. This indicates that a unit increase in real GDP per capita reduces CO_2 emission by 0.87% and a unit increase in tourist activities increases the CO_2 emission by 0.257%. As for FE, some of the variables, such as tourism, and dummy variables for post-Brexit countries, and degree of global financial, are not significant variables in this regard, thus accounting for no actual effects on the CO_2 emission.

For all other countries in the 'Others' category (Spain, Belgium, Cyprus, Ireland, the UK, Portugal), these are countries in the rest of the EU, which are grouped as 'other' and shown in Table 4 column 6 and Table 5 columns 6 and 9. Under pooled-OLS, four explanatory variables, which are energy consumption, tourism, dummy variables for Brexit, and global financial crisis, are significantly related to carbon emission. The coefficients of these variables imply that a unit increase in them gives rise to 0.06% increase, 0.89 increase, 0.3% decrease, and 0.15% decrease in carbon emission in the grouped countries. Regarding FE and RE estimation, the only significant variable, among others, is energy consumption. The corresponding coefficient in each model revealed 1.01% and 0.98% increase in CO_2 as a result of unit percent increase in energy consumption.

Hausman test is a test to determine which model between FE and RE is best fit to estimate panel data series. The null hypothesis is that the model is random effect model. If this hypothesis is rejected, the fixed effect model will be employed and, thus, pooled-OLS and RE estimates will be inefficient, because pooled-OLS only yields consistent estimates when the RE model is true. In this study,

Table 6
Results for main model estimation across several techniques compared with System GMM − all EU countries.

Main results (Dep. Variable: CO_2, log)				
VARIABLES	Pooled OLS	Fixed Effects	Random Effects	One-Step System GMM
LRGDP	1.903***	0.569	0.625	0.434***
	(0.385)	(0.615)	(0.502)	(0.117)
LRGDP2	−0.0966***	−0.0298	−0.0330	−0.0218***
	(0.0196)	(0.0345)	(0.0280)	(0.00591)
LTOUR	0.0704***	−0.0800**	−0.0770***	0.00174
	(0.0166)	(0.0310)	(0.0283)	(0.00368)
LENC	0.946***	0.990***	0.997***	0.0265*
	(0.0146)	(0.207)	(0.144)	(0.0145)
ECI	−0.104***	0.0862	0.0819	−0.00893
	(0.0258)	(0.0612)	(0.0583)	(0.00619)
DBREXIT	−0.209***	−0.0476***	−0.0477***	0.00609
	(0.0677)	(0.0108)	(0.00971)	(0.00436)
DGREECEGFC	−0.129**	−0.0100	−0.00996	−0.0245***
	(0.0643)	(0.00608)	(0.00634)	(0.00450)
Alpine	−0.0982**		−0.325**	
	(0.0420)		(0.151)	
Baltic Sea	0.0303		−0.267	
	(0.0414)		(0.296)	
Danube	0.121***		−0.172	
	(0.0374)		(0.158)	
Others	0.0689***		−0.0808	
	(0.0245)		(0.141)	
Constant	−9.217***	−0.658	−0.789	−2.138***
	(1.957)	(3.415)	(2.703)	(0.569)
Year Dummies	Yes	Yes	Yes	
Observations	624	624	624	572
R-squared	0.968	0.730		
Instruments/Groups				467/26
AR (2) p value				0.159
Number of country ID		26	26	26

Robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7
Results for main model estimation across several techniques compared with System GMM − EU countries without the UK.

Main results (Dep. Variable: CO_2, log)				
VARIABLES	Pooled OLS	Fixed Effects	Random Effects	One-Step System GMM
LRGDP	1.936***	0.570	0.623	0.431***
	(0.389)	(0.634)	(0.522)	(0.117)
LRGDP2	−0.0979***	−0.0300	−0.0330	−0.0216***
	(0.0199)	(0.0356)	(0.0292)	(0.00591)
LTOUR	0.0707***	−0.0810**	−0.0781***	0.00161
	(0.0168)	(0.0314)	(0.0288)	(0.00358)
LENC	0.942***	0.993***	0.998***	0.0261*
	(0.0152)	(0.212)	(0.151)	(0.0146)
ECI	−0.116***	0.0929	0.0886	−0.00939
	(0.0268)	(0.0615)	(0.0593)	(0.00624)
DBREXIT	−0.216***	−0.0450***	−0.0451***	0.00795*
	(0.0704)	(0.0108)	(0.00978)	(0.00410)
DGREECEGFC	−0.175***	−0.0120*	−0.0119*	−0.0249***
	(0.0676)	(0.00594)	(0.00625)	(0.00467)
Alpine	−0.0869**		−0.331**	
	(0.0425)		(0.154)	
Baltic Sea	0.0324		−0.270	
	(0.0416)		(0.301)	
Danube	0.130***		−0.177	
	(0.0378)		(0.160)	
Others	0.0567**		−0.0868	
	(0.0244)		(0.161)	
Constant	−9.395***	−0.651	−0.756	−2.126***
	(1.979)	(3.503)	(2.822)	(0.570)
Instruments/Groups				461/25
AR (2) p value				0.165
Observations	600	600	600	550
R-squared	0.965	0.723		
Number of country ID		25	25	25

Robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

the hypothesis of random effect model is not rejected since p-value>0.05. Thus, the suitable method for the regression model is the RE model [Hausman Test → chi2 (7) = 13.21 and Prob > chi2 = 0.0672).

Table 6 shows the comparison of pooled-OLS, FE, and RE estimation with One-step system GMM (GMM) for all the EU countries (before UK exit). Their real GDP capital is highly significant at 1% in pooled-OLS and GMM estimation, but not significant in both FE and RE. The significance indicates that a unit increase in real GDP per capita increases the CO_2 emission by 1.90% and 0.43% in pooled-OLS and GMM estimators, respectively. The same thing was observed for LRGDP2, but with negative significant impact on CO_2. All the variables under pooled-OLS including country specific are significant predictors of CO_2 unlike FE and RE where only tourism, energy consumption, and Brexit are significant predictors of carbon emission. Under the GMM model, only energy consumption and global financial crisis significantly predict emission. A unit percent increase in energy consumption increased the emission by 0.03% while a unit percent increase in global financial crisis leads to 0.02% reduction in CO_2.

Table 7 shows the comparison of pooled-OLS, FE, and RE estimation with One-step system GMM (GMM) for all the EU countries without the UK. Their real GDP capita is highly significant at 1% level of significance in pooled-OLS and GMM estimation, but not significant in both FE and RE. The significance indicates that a unit increase in real GDP per capita increases the CO_2 emission by 1.90% and 0.43% in pooled-OLS and GMM estimators, respectively. The same thing was observed for LRGDP2, but with negative significant impact on CO_2. All the variables under pooled-OLS, including country-specific (except Baltic Sea) are significant predictor of CO_2 unlike FE and RE where only tourism, energy consumption, and Brexit are significant predictors of carbon emission. From the result, tourist activities release small of emission in post-Brexit countries as an increase in tourism adds 0.07% increase to the environmental emission. Under the GMM model, only energy consumption and global financial crisis significantly predict emission. A unit percent increase in energy consumption increased the emission by 0.03%, while a unit percent increase in global financial crisis leads to 0.02% reduction in CO_2, meaning that more usage of energy-related activities contributes to the emanation of carbon dioxide in post-Brexit countries.

5. Conclusion and policy implications

The aim of this study is to examine the environmental consequence of economic complexities and tourism in the EU, with special considerations for the role of Brexit and the Greece bailout crisis. To achieve this aim, a one-step system Generalized Method of moment (GMM) model is adopted in comparison with pooled Ordinary Least Squares (pooled-OLS) regression, and fixed effect (FE) and random effect (RE) estimation. Also, additional control variables such as real GDP per capita, coal rent and energy consumption were included to analyze the environmental degradation in the EU proxied by carbon dioxide emission.

Firstly, the analysis was carried out across EU macro regions (Adriatic-Ionia, Alpine, Baltic Sea, Danube, Others) which consist of different countries. The study finds that, in some regions, real GDP per capita, energy consumption, tourist activities and ECI are statistically significant determinants of CO_2 emission. This is in tandem with the study of Buhari et al. (2020) who found a strong association between energy usage, ECI, and economic growth on CO_2 emission. In other regions, it was observed that tourism, ECI, dummy variables for Brexit, and global financial crisis have no significant impact on carbon emission. Thus, the occurrence of international travel, free economy, and financial crisis does not impact the environmental problem in such regions.

Secondly, when pre-estimation analysis of several techniques employed was tested using Hausman test, it was observed that FE may not be the best approach, and pooled-OLS may be weak too. Thus, the GMM model is used since it controls for serial correlation, heteroscedasticity, and endogeneity problem and this technique is maintained for the main result of the all the EU countries with and without the UK (due to Brexit). For EU countries with the UK, the findings, under RE estimations, suggested that real GDP per capita growth is not significant, but tourism, energy consumption and dummy Brexit are significant in predicting carbon emission. However, while controlling for serial correlation (using GMM), real GDP per capita, energy consumption, and global financial crisis significantly predicted environmental degradation. The same results were observed for the EU without the UK, except that dummy Brexit is now significant. These outcomes are consistent with the study of Shahzad et al. (2020) on the United States as well as Neagu (2019) for 25 European Union countries and Apergis and Payne (2009) for six countries in Central America.

In conclusion, there are no effects of ECI on carbon emission in both cases, thus policy makers should synergize more approaches that enhance structural change in EU economies. Also, since increase in energy consumption and tourism leads to increase and decrease in CO_2 as found in the study, policy makers should find ways of introducing advanced technology that will prevent environmental degradation from usage of energy and more strength should be channeled to improving tourist activities in the countries.

Despite the good results of this study, there are, however, some limitations on which future research can possibly be focused. The authors did not include the Covid-19 pandemic as a contributing factor to the environment. Also, some other explanatory variables, such as trade openness to control for international trade among the groups, can be included. Furthermore, the study didn't split the energy consumption into renewable and nonrenewable energy, thus future researches can, therefore, measure these types of energy to account for which one exactly (renewable or nonrenewable) contributed majorly to the emission in each group.

CRediT authorship contribution statement

Festus Fatai Adedoyin: contributed to idea conceptualization of the study. **Phillips O. Agboola:** design. **Ilhan Ozturk:** supervising and manuscript editing. **Festus Victor Bekun:** literature search. **Mary Oluwatoyin Agboola:** analysis and conclusion.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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