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APPLIED ECONOMICS OF ENERGY AND ENVIRONMENT IN SUSTAINABILITY

Air pollution and tourism growth relationship: exploring regional dynamics in five European countries through an EKC model

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Abstract

The present study intends to explore the relationship between tourism growth and air pollution at a regional level for five important tourism European destinations: France, Spain, Greece, Portugal, and Italy. Most of the studies found in the literature examine this relationship on a national scale and focus only on the CO_2 pollutant, which is a greenhouse gas but not a critical pollutant in terms of air quality and human exposure. This research focuses on a regional basis (NUTS 2 classification) and takes into account the main critical pollutants in terms of urban air pollution (namely: NOx, PM10, and PM2.5), and considers 10 years, from 2009 until 2018. This work aims to investigate evidence of a tourism-induced Environmental Kuznets Curve (EKC) for the countries through the construction of five panels, one for each country, including different variables: the Gross Domestic Product, the energy consumption, and the number of nights spent at tourist accommodation establishments from both domestic and foreign tourists. The Levin-Lin-Chu unit root test proves the variables to be stationary, while the Pedroni cointegration test shows that they are integrated. The pooled OLS estimator is employed throughout the countries to check the relationship among the variables. Results reveal that the tourism-induced EKC hypothesis is not validated for any of the countries. The findings also show that in Portugal, Italy, and Greece, there is a negative relationship between economic growth and environmental pollution, while mixed evidence is found for France and Spain. Moreover, differences in the impacts of international and domestic tourists on air pollution are found: foreign tourists negatively impact emissions, while domestic ones increase them. This result is clear for Spain, Greece, and Italy. The Granger panel causality test is then conducted to see the causality among the variables.

Keywords Tourism · Air pollution · NUTS 2 regions · European countries · Tourism-induced Environmental Kuznets Curve (EKC)

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Table 1 Share of GDP generated by the travel and tourism industry worldwide

		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
World	%	9.6	9.3	9.4	9.5	9.6	9.7	10	10.1	10.3	10.4

Source: Reworked data taken from Lock–2020.

Table 2 Total impact (direct, indirect, and induced) of travel and tourism industry on GDP per year in the five European countries analyzed

Country		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
France	%	9.63	9.06	9.84	9.12	9.57	9.45	9.51	9.32	9.35	9.54
Spain	%	13.58	13.26	13.55	13.75	13.82	14.15	14.04	14.17	14.53	14.57
Greece	%	16.66	15.56	16.03	15.73	17.41	18.17	19.20	19.13	19.95	20.58
Portugal	%	12.56	13.81	14.66	15.42	16.00	17.24	17.12	17.65	17.89	19.08
Italy	%	9.93	9.87	10.50	11.14	11.67	12.14	12.75	12.71	12.99	13.18

Source: Elaborated based on World Travel & Tourism Council (2020).

Introduction

The tourism industry is one of the main economic activities in the world. Tourism is considered an "engine of economic growth" (De Vita et al. 2015, p. 16,652). Its development requires huge investments, especially in infrastructures (e.g., airports, roads) and in other tourism facilities (e.g., hotels and resorts, restaurants, shops) Its activity creates hundreds of million jobs, accounting, in 2019, for 10.6% of global employment (considering direct, indirect and induced impacts) and for about 10.4% of Gross Domestic Product (GDP) (World Travel & Tourism Council 2020). As may be observed in Table 1, tourism impact on GDP has increased across the years. Although the impact of tourism on GDP decreased, in 2020, in consequence of the COVID-19 pandemic to 5.5%, tourism is one of the most resilient economic activities, and forecasts point that tourism will continue to grow.

Tourism is an important source of economic growth and development (Danish and Wang 2019). However, there are numerous economic, social, and environmental negative effects associated with this industry. Hence, this industry is a substantial contributor to environmental degradation (Bella 2018; Danish and Wang 2019; Dogru et al. 2020; Lenzen et al. 2018), putting pressure on the quality of the environment by depleting its natural resources. Recently, there have been increasing concerns about the negative impacts of tourism development on the environment, in particular in Mediterranean countries (Gao and Zhang 2021) including those regarding air quality impact (Deng et al. 2017; Eusébio et al. 2021; Russo et al. 2020; Saenz-de-Miera et al. 2014).

Besides the direct links between tourism activity and the generation of air pollution, this relationship is still poorly investigated, and limited to the CO_2 pollutant (Dogru et al. 2020; Isic et al. 2017a, b; 2020), which is a greenhouse gas but not a pollutant with health effects. Only a limited number of studies examine the impact of tourism on other pollutants (e.g., NOx, PM10, PM2.5) (Russo et al. 2020). Moreover, air pollution also negatively influences tourism demand to several destinations (Carneiro et al. 2021a, b; Peng and Xiao 2018; Saura et al. 2018; Wang et al. 2021). Nevertheless, the number of studies in this scope is very scarce. Therefore, the present study aims to investigate the relationship between NOx, PM10, PM2.5 emissions, economic growth, domestic and foreign tourism, and energy consumption, in the five countries, which are considered important European tourism destinations—Portugal, Greece, France, Spain, and Italy—with the last three countries respectively being the first, the second, and third most visited countries in Europe (UNWTO 2018). Furthermore, in these countries, tourism is one of the most important industries as may be seen in Table 2.

The relationship between pollutants emissions, economic growth, domestic and foreign tourism, and energy consumption, will be analyzed using the Environmental Kuznets Curve (EKC) model as reference. According to Stern (2004, p. 1419), the EKC is defined as a "hypothesized relationship between various indicators of environmental degradation and income per capita that exhibits an inverted U-shape during the process of economic development of an economy," therefore explaining the relationship between the quality of the environment and economic growth (Dogru et al. 2020; Gamage et al. 2017). It is also intended to check whether the tourism-induced EKC hypothesis is confirmed for the five countries selected for the period 2009–2018 on a regional scale, according to the European Union NUTS 2 classification. The incorporation of tourism as an independent variable serves to capture the idea that tourism development could, at the same time, significantly affect economic growth and pollution level, since it characterizes the prosperity of the tourism

industry on the level of emissions. Tourism, therefore, could be considered as a driver of economic growth and/or a driver of environmental degradation, even though it is still difficult to determine to what extent it contributes to both (Chan et al. 2020). Some studies show that economic growth leads to tourism revenue growth and vice versa. Therefore, the tourism industry has a direct positive effect on the economic growth (Paramati et al. 2017), especially of developed countries (Işik et al. 2017a, b), as it is found for France, Greece, and Italy (Dritsakis 2012), for Portugal (Aslan 2013), and Spain (Balaguer et al. 2002).

This research is based on previous studies, whose aim was to investigate the relationship among these variables and the existence of a tourism-induced EKC at the national level, generally focusing only on CO_2 emissions (Chan et al. 2020; Paramati et al. 2017), therefore neglecting the other pollutants responsible for the degradation of the air quality and that are also consequences of tourism development. This study adopts panel data techniques, constructing a separate panel for all of the five countries, each of which is composed of the specific country's regions.

This study constructs an EKC model, incorporating NOx, PM10, and PM2.5 emissions per capita, economic development (GDP and square of GDP per capita), a tourism variable for domestic tourists and another for foreign tourists, and energy consumption, to find evidence of a tourism-induced Environmental Kuznets Curve. This research contributes to the existing literature in several aspects: (i) for adding empirical evidence of the EKC linked to the tourism sector, as there are very few studies with these concrete objectives and application; (ii) for analyzing the topic at the regional level, which is a novelty especially concerning tourism-induced EKC; and (iii) by exploring the causal relationship among the variables taking into account three pollutants as environmental degradation proxy, not including CO_2 as it is commonly made in the literature.

The rest of the article develops as follows. "Theoretical framework" section presents the literature review about tourism impacts on the environment, the consequences that the environment has on tourism demand, and also the previous tourism-induced EKC researches' results. "Data description, sources, and methodology" section describes the data (and its sources) employed in the present study, with a focus on the pollutants selected for the analysis, and the methodological approach used, while "Empirical results" section presents the main results of the empirical study. In particular, it reports the estimates of the panel unit root test, namely the Levin-Lin-Chu test, for each of the variables, and the panel cointegration test's outcomes obtained from the Pedroni test. The analysis continues by investigating the presence of tourism-induced EKC for all the five countries, through the use of a common model, the pooled OLS estimator, and other ones varying from country to country according to their goodness in statistically describing the regions. Finally, the short-run causality among the variables is explored through the panel Granger causality test. Then a discussion and policy recommendations section, derived from the empirical findings, and finally the conclusions section which also insights for future research.

Theoretical framework

Tourism effects on the environment

Tourism can induce a large pressure on the environment in the form of soil erosion, degradation of monuments and historic sites (cultural effect), deterioration and reduction of green fields, loss of natural habitat, biodiversity, and landscape (Russo et al. 2020; Jones and Munday 2004).

The environmental effects caused by the tourism industry are greater than other service sectors' ones (except for hazardous industrial waste), particularly the impacts caused on air quality (Hsieh et al. 2013). This is because an increment in tourism activities causes an increased demand for energy from numerous activities such as accommodation, catering, infrastructures' construction, tourist attractions (Nosheen et al. 2021; Zeng et al. 2021; Katircioglu 2014a; Pu et al. 2011) and, especially, air and road transportation, widely used in the scope of tourism (Nosheen et al. 2021; Hsieh et al. 2013). All these high energy-consuming activities negatively affect the environment across countries generating different air pollutants (Shaheen et al. 2019), especially greenhouse gases emissions, mainly CO_2 ones, which are an inevitable by-product of tourism activities (Nepal et al. 2019; Ren et al. 2019; Bella 2018) and makes the tourism sector one of the main causes of climate change (Shaheen et al. 2019). In fact, according to the World Tourism Organization (UNWTO), the tourism sector accounts for 4.6% of global warming, and this is the reason why the tourism industry is frequently labeled as an "industry without a chimney" (Hsieh and Kung 2013, p. 659).

As a great share of all man-made CO_2 emissions is due to tourism, the majority of the literature about air quality and its causes focuses on this air pollutant (Nepal et al. 2019; Ren et al. 2019; Balli et al. 2018; Bella 2018). Although CO_2 pollutant is a problem for climate change issues (greenhouse effect), it is not a threat to air quality and human health. Some studies already suggest that tourism has an impact on other air pollutants such as NOx, PM10, and PM2.5 (e.g., Zeng et al. 2021; Russo et al. 2020; Robaina et al. 2020; Zhou 2019; Lee et al. 2015; Saenz-de-Miera and Rosselló 2014), which have greater negative effects on human health. However, the literature in this field is scarce. This paper aims to analyze the relationship between tourism and some of

the most critical pollutants for human health, namely NOx, PM10, and PM2.5 emissions.

Environmental effects on tourism demand

Even though Lee et al. (2015) report that tourism has significant effects on environmental quality, while the quality of the environment has no significant impacts on tourism, most of the literature do not corroborate this issue.

For instance, Campón-Cerro et al. (2020) show that tourism experiences based on water, offer experiential value to tourists, affecting their quality of life, satisfaction, and loyalty. Moreover, multiple factors or attributes influence a destination's competitiveness, which may include the level of local prices, the safety at the destination, and, most of the time, the environmental conditions, which are considered relevant determinants in the selection of destinations by visitors, such as air quality (Fernandez et al. 2020; Huybers et al. 2000; Rodrigues et al. 2021; Tang et al. 2019; Zhang et al. 2015). Some studies reveal that air quality may influence visitors' satisfaction (Peng and Xiao 2018; Saura et al. 2018; Wu et al. 2018), destination image (Becker et al. 2017; Peng and Xiao 2018), and travel behavior (Carneiro et al. 2021a).

It is important, therefore, to investigate the relative importance of the environment, including air quality, to tourist destinations' choices, as it can not be taken for granted that all tourism destinations will have a good quality environment (Gossling et al. 2015; Huybers and Bennett 2000). Hence, the quality of the environment is one of the most important attractiveness factors in some tourism destinations (Dong et al. 2019; Giddy and Webb 2016).

Air quality influences physical and mental comfort, being one of the major criteria to assess the suitability of tourism activities and to select tourism destinations (Rodrigues et al. 2021; Zhang et al. 2015). The research of Dong et al. (2019) presents evidence of people's dislike regarding air pollution, and their unwillingness to stay in polluted places, demonstrating how clean air is a pull motivational factor for traveling. Particularly, air pollution and climate changes are negatively affecting tourism development, as empirically evidenced by Gossling et al. (2015).

Other evidence shows that tourists attach a relatively high monetary value to holiday destinations with a relatively good environmental quality, as demonstrated by the research conducted by Huybers and Bennet (2000). This piece of the literature shows how potential overseas tourists were willing to pay a substantial premium to visit a destination with a high level of environmental quality. Moreover, this study also reveals the visitors' willingness to pay more for efforts to preserve the current environmental quality in the future.

The study of Tang et al. (2019) carried out in the city of Beijing, found that air pollution harms the city's tourist arrivals in the long run, while the variations in air quality do not influence Beijing's tourist arrivals in the short term. The short-run effects are likely to be related to the travel decision, while the long-run effects might capture the impact on the destination's image, for which the environmental condition matters the most.

Tourism-induced EKC

The relationship between the expansion of tourism and the Environmental Kuznets Curve has gained importance in the 2000s, the moment in which a large number of environmental protection policies arose and became visible in the tourism policy agenda (Zaman et al. 2016). The majority of the researches concerning the tourism-induced EKC are conducted at a national scale and used as a proxy for environmental degradation CO_2 emissions. We complement the existing literature, exploring evidence of a tourism-induced EKC at a regional level including a set of three pollutants. Regarding the tourism proxy, the current literature is mainly divided into tourism receipts (tourism expenditures) and several international tourist arrivals proxies (mainly counting the nights spent in touristic accommodation establishments).

At a regional level, two recent studies about China's regions have been conducted regarding the tourism-environmental degradation relationship (Chan et al. 2020; Zhang et al. 2016). This country has a vast territory. It is not internally homogenous and, therefore, a large variation across regions exists in terms of both numbers of tourist arrivals and CO_2 emissions. Zhang et al. (2016) conducted a study to empirically investigate whether the tourism-induced EKC hypothesis holds for China at a regional scale for the period 1995–2011. The study uses as a tourism proxy the number of tourism receipts. Moreover, it includes a variable for energy consumption and incorporates GDP per capita to represent economic growth. It shows that tourism causally affects both CO_2 emissions and economic growth and that, in turn, economic growth interacts with CO_2 emissions, therefore confirming the tourism-led growth hypothesis. However, a tourism-induced EKC hypothesis is only weakly supported in some regions of China, while it does not exist for the regions in the central part of the country.

More recent research (Chan et al. 2020) has been conducted over China's 30 provinces for the period 1997–2015. A panel Vector Error Correction Model (VECM) has been used to test the tourism-induced EKC for the short and long run. Conclusions were that the CO_2 level converges slowly to its long-run equilibrium and that an inverted U-shaped relationship is not evident in the short run.

No evidence of a regional tourism-induced EKC has yet been found, while at a national scale, many studies have provided evidence for it, all employing economic growth and energy consumption variables, CO_2 emissions as a proxy for

environmental degradation, and integrating tourism development within the EKC model. Through the Dynamic Ordinary Least Squares (DOLS) method, Katircioglu (2014b) validates the tourism-induced EKC for Singapore and De Vita et al. (2015) for Turkey. Ozturk et al. (2016), employing the generalized method of moments (GMM), showed that the EKC hypothesis exists only in the upper-middle-income and high-income countries. This study reveals that environmental degradation decreases with the increase in income, confirming the EKC. The reason behind this is that when a country's income gets greater, it will increase its attention and resources for the environment and its protection, creating a more responsible attitude towards it.

Concerning tourism-induced EKC evidence about France, Spain, Greece, Portugal, and Italy, Zaman et al. (2016) constructed a tourism development index, through the principal component analysis. This is a weighted index of all different tourism drivers (such as international tourism expenditures, international tourism receipts, and the number of international tourist arrivals) into one. Through a panel of 34 selected countries (developed and developing ones) for 9 years (2005–2013), a panel two-stage least square technique was used to show how GDP per capita rises along with the increase of the tourism development index. Moreover, it initially deteriorates the environmental quality, while at later stages of development, the second-order coefficient of GDP decreases CO_2 emissions per capita, therefore demonstrating the EKC validity for the countries examined. Additionally, the tourism index has a significant positive impact on carbon emissions, which indicates that the tourism sector considerably affects the environmental quality at a national scale in the selected panel of countries.

A paper regarding a panel data of ten tourism-induced countries (including France, Spain, and Italy) for the period 1995–2016, through the use of the Fully Modified OLS method (FMOLS), shows that the income deriving from tourism causes an increase in GDP, which at first substantially increases the CO_2 emission level. The square of GDP per capita, instead, significantly decreases carbon emissions, therefore confirming the EKC hypothesis across the countries (Shaheen et al. 2019). The tourism-induced EKC is also confirmed for France at a national level by Bella (2018), who incorporates the tourists' arrivals into the EKC model and considers the CO_2 emissions from touristic transportation for the period 1995–2014, through the VECM estimation. In contrast, Gao et al. (2019) employ the FMOLS estimation to show how the existence of tourism-induced EKC (considering CO_2 emissions as a proxy for environmental degradation) is only validated in Cyprus, Lebanon, and Libya at the country level, while all the other Mediterranean countries, including Italy, France, Greece, and Spain do not present shreds of evidence of an EKC over the period 1995–2010.

For the same period, the same authors published another research (Gao and Zhang 2021), whose purpose was still to analyze the tourism sector's environmental impact for eighteen Mediterranean countries at a national scale, but this time checking whether the existence of a tourism-induced EKC hypothesis holds for different air pollutants, besides CO_2 emissions (namely CO, SO_2, NOx, PM10, and PM2.5). Conducting the FMOLS, the results confirmed the EKC for the Southern Mediterranean countries for several pollutants: CO, SO_2, and particulate matters, while it was not found for CO_2 emissions. Instead, for the Northern countries (including the ones analyzed in this article), no tourism-induced EKC was documented, for any of the pollutants.

Summing up, no tourism-induced EKC is validated at a regional level. On a national scale, instead, mixed evidence of EKC is found in the existing literature, especially for what concerns the countries analyzed in this study. In both cases, normally environmental degradation is proxied by CO_2 emissions; additionally, whenever other pollutants have been included in the models, a tourism-induced EKC did not result to be confirmed for France, Spain, Greece, Portugal, and Italy.

Data description, sources, and methodology

To find evidence for a tourism-induced Environmental Kuznets Curve hypothesis, different variables have been selected to explore the relationship between tourism growth, economic development, energy consumption, and air pollution. These variables are closely related to each other: tourists' arrivals in a country tend to increase the destination's economic growth, yet they may also adversely affect the environmental quality of it due to the high energy consumptive touristic-related activities (Nosheen et al. 2021; Tsui et al. 2018). Therefore, exploring these variables in a holistic approach is fundamental.

In terms of the economical proxy, this study uses the per capita Gross Domestic Product in million euros at constant prices as a proxy for the per capita income of each country. Regarding the tourism data, the number of nights spent at tourist accommodation establishments (i.e., hotels, holiday and other short-stay accommodation, camping grounds, recreational vehicle parks, and trailer parks) from both domestic and foreign tourists is used. The tourism data is divided into foreign and domestic markets also in values per capita. The energy use variable is proxied by energy consumption in kWh/capita, without differentiating from which sector it is consumed from. The air quality degradation—the dependent variable under consideration—is proxied by emissions in metric tons per capita. Concentrations reflect better the air quality, but due to the unavailability of data at the regional

Table 3 The number of regions analyzed for each country

Country	Number of (NUTS2) regions
Portugal	7
Italy	20*
France	22**
Spain	19
Greece	13

*Italy's NUTS 2 2016 classification has 21 regions since Trentino Alto-Adige is divided into the 2 autonomous provinces of Bolzano and Trento, which will be considered as a single region in this study, as lack of separated data for all the variables is recurrent. **France's NUTS 2 2016 classification has 22 regions + 5 overseas regions, which will not be considered in this analysis, as there is no availability of pollution data for them. Source: Eurostat Data Browser.

level for all the countries and the impossibility to have per capita data, emissions have been preferred for the present study. The pollutants selected include the most critical air pollutants in terms of urban air quality (Rasli et al. 2018): nitrogen oxides (NOx) and particulate matter (namely PM10 and PM2.5), as mentioned above.

The data presented are annual time series covering the period 2009–2018 in a panel of five European countries: France, Spain, Greece, Portugal, and Italy. The analysis is performed on a regional level (NUTS 2), considering the current NUTS 2016 classification (GISCO 2020).[1] The number of observations varies according to the number of regions each country has, as Table 3 shows.

Nitrogen oxides

Nitrogen oxides (NOx) is a generic term for nitric oxide (NO) and nitrogen dioxide (NO2). The emissions from these two compounds can derive from natural and anthropic origins.

Regarding the first category, the emissions are originated by wildfires, lightning, microbial activity of organic compounds in soils, and biological processes in the oceans. On a global scale, they represent less than 30% of total emissions. Human activities are, instead, the dominant source of nitrogen oxides (European Environment Agency 2019; Delmas et al. 1997). This includes the combustion of fossil fuels, which is responsible for 50% of global emissions (Delmas et al. 1997), biomass burning, power generation, and transportation, due to the gasoline and diesel engines.

According to the European Environment Agency (EEA) data from 2019, transportation is the major source of nitrogen oxides accounting for 45% of all human-produced NOx emissions, with road transport being the main emitter, even though shipping and aviation also substantially contribute to air pollution. Emissions from ships increase concentrations of SO_2 and PM, but especially of NOx since shipping is responsible for 18–30% of all the world's nitrogen oxide pollution (Schrooten et al. 2009). Aviation also is an important contributor to air pollutants, especially to NOx emissions, particularly generated by landing and take-off (LTO) cycles: 16.29 kg of NOx emissions are released in the air every LTO (Bo et al. 2019).

Energy production and distribution is the second most NOx emitting sector, and this is also hugely influenced by the tourism industry since this latter requires a lot of energy consumption for various functions. Tourism activities involve energy consumption both directly and indirectly, respectively through fossil fuels and electric power (Dogan et al. 2017). The World Summit on Sustainable Development in Johannesburg in 2002 has acknowledged international tourism as one of the major energy-consuming sectors (UN Report of the World Summit on Sustainable Development in Nepal 2008).

Particulate matter

Particulate matters (PMs) are inhalable and respirable particles with a diameter of fewer than 10 μm (PM10), including fine particles less than 2.5 μm (PM2.5). As for the NOx emissions, the sources of particulate matter can be natural or man-made.

Particulate pollutants are produced naturally from volcanic eruptions, wildfires, wind and dust storms, rock debris, a reaction between gaseous emissions, soil erosion, and sea spray, which all inject millions of tons of particulate matter every year.

Human-generated particles include the burning of gas and oil in motor vehicle engines (transportation), industrial processes, and especially large amounts of particles that are emitted by power generators and fuel combustion for energy production in industrial activities (building, mining, manufacture of cement, ceramic and bricks, and smelting), households (heating, lighting, cooking), and road transport, especially diesel engines.

Data collected from the EEA (2019) shows how aviation, shipping, and road transport PM emissions' quantities are

[1] GISCO (2020). Geographical information and maps; https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/nuts#nuts16

Table 4 Descriptive statistics of the 3 pollutants for each country

France	Mean	Std. Dev	Min	Max
NOx	90,853.15	45,880.33	17,063.11	235,171.8
PM10	26,289.84	15,646.59	1442.74	79,671.54
PM2.5	17,818.08	7508.106	1771.39	45,839.06
Spain	Mean	Std. Dev	Min	Max
NOx	81,732.16	61,852.54	285.51	270,739
PM10	20,130.86	16,621.93	79.64	83,378.5
PM2.5	11,706.08	9260.73	47.78	57,167.63
Greece	Mean	Std. Dev	Min	Max
NOx	43,561.24	35,805.9	5914.38	183,551.2
PM10	10,171.55	10,659.95	844.98	55,839.41
PM2.5	5011.012	4418.166	684.13	25,073.77
Portugal	Mean	Std. Dev	Min	Max
NOx	1107.567	916.5461	4.58	3161.52
PM10	315.5112	248.0681	2.83	763.01
PM2.5	264.1496	211.0227	2.19	611.78
Italy	Mean	Std. Dev	Min	Max
NOx	72,101.92	63,077.42	4266.91	315,306.7
PM10	17,025.41	15,348.64	1002.54	68,100.81
PM2.5	15,159.34	13,476.57	963.3	64,386.19

Unit: metric tons.

residual when compared to industry, especially stationary combustion, which accounts for residential combustion emissions due to cooking and heating (Russo et al. 2020). The contribution of tourism to these activities is non-negligible as they are energy-intensive: if tourism grows, the electricity consumption will rise more and more, since tourist overnight stays increase the electricity use especially concerning the food/beverage and hospitality sectors (Pablo-Romero et al. 2017). Industrial processes are associated with tourism regarding all the constructions this industry requires, and it accounts for about 12% of all the PM2.5 emissions. The other way around also holds: Liu et al. (2019) in their work particularly emphasize the impact of PM2.5 concentration on tourism, as this impact on the visitors is direct, therefore important to be analyzed.

Data statistics and sources

The summary statistics (mean, standard deviation, minimum, and maximum values) for the three different air pollutants are reported in Table 4, aggregated at the national level, resulting from the values of each country's regions, for the period 2009–2018.

The source for the pollutants was the EMEP/CEIP (Cooperative program for monitoring and evaluation of long-range transmission of air pollutants in Europe) website,[2] and the gap-filled gridded emissions were obtained with a 0.1×0.1 (longitude/latitude) resolution.

As shown in Table 4, there is a large variation of the number of emissions across the countries, even though NOx is the largest pollutant, followed by PM10 and PM2.5 for all of them.

For every pollutant, Portugal is the country with fewer emissions, whereas France is the one that emits the most. It is obvious that the territorial dimension of each region and country matters; therefore, it is something to take into account when interpreting the data.

Regarding NOx, the mean of the emissions ranges from 1107.57 in Portugal, until getting to 90,853.15 in France, while the mean for PM10 emissions goes from 315.51 to 26,289.84, for the same countries respectively. For these two pollutants, France is followed by Spain, Italy, and Greece, in terms of emissions. For PM2.5, the emissions range from 264.15 in Portugal to 17,818.08 in France, this time followed by Italy, Spain, and Greece.

Table 4 shows the general countries' pollutants overview, at a country level, even though the analysis will be conducted with air pollutants emissions in tons per capita, considering each region's population. The data for GDP and tourism were obtained from the Eurostat Data Browser. The energy data were gathered from different sources: for France, from the Open Data Réseaux Énergies database, RED eléctrica de España has provided the Spanish numbers; for Greece, the Hellenic Statistical Authority was used; and for Portugal and Italy, data was taken from the Instituto Nacional de Estatística (INE) and Terna, respectively.

Methodology

This study intends to examine whether the existence of a tourism-induced EKC hypothesis holds at a regional level for the five selected countries and if it is valid for the three different air pollutants. To do this, the relationship between air pollutants, economic development, tourism growth, and energy consumption is explored by using the EKC model outlined in Eq. (1).

$$\begin{aligned}\text{Pollutant}_{ijt} = {} & \beta_0 + \beta_1 \text{GDP}_{ijt} + \beta_2 \text{GDP2}_{ijt} + \beta_3 \text{TOUFO}_{ijt} \\ & + \beta_4 \text{TOURE}_{ijt} + \beta_5 \text{ENE}_{ijt} + \varepsilon_{ijt}\end{aligned} \quad (1)$$

Pollutant denotes the NOx, PM10, and PM2.5 per capita emissions, while GDP and GDP2 refer to per capita GDP and the squared term of per capita GDP, respectively; TOUFO represents the nights spent at tourist accommodation establishments by foreign people, whereas TOURE by domestic tourists. Lastly, ENE refers to energy consumption. It is important to highlight that the natural logarithm of all variables is used in the econometric analysis. The subscripts i and j characterize the region and the country, respectively, while the subscript t denotes time, i.e., the years. Finally, ε_{ijt}

[2] EMEP/CEIP (2020). Grid emissions in 0.1°×0.1° long-lat resolution; https://www.ceip.at/the-emep-grid/gridded-emissions

is the error term. This model will be useful to check whether there is causality at a regional level among all the variables.

Equation 1 seeks to confirm whether there is evidence of EKC, that is, whether there is an inverted U-shaped curve between economic growth and environmental impact, in this study, translated into emissions of air pollutants. For this hypothesis (EKC) to be verified, there must be a positive relationship between economic growth and emissions, but at a certain point, this relationship reverses (negative), justifying the introduction of the variable of economic growth to the square. Furthermore, as we intend to have an EKC model applied to tourism, the variables of foreign tourism and domestic tourism were introduced, to see how each type of tourism affected these emissions. Finally, as energy consumption is one of the main sources of atmospheric emissions, both for the tourism sector and the economy in general, it is important to include this variable in the equation.

The coefficients of these variables can be interpreted as the long-run elasticities of pollutant emissions concerning the corresponding variables. According to the EKC theory, we then expect β_1 to be greater than zero and β_2 to be less than zero. Furthermore, the sign of β_5 is expected to be positive since energy consumption tends to lead to an increase in emissions. We do not make predictions about the signs of β_3 and β_4 coefficients, once the literature points mixed evidence.

A panel for each of the five countries has been created, and each one of them is divided/structured in NUTS2 regions: all the analysis is conducted on a regional level, using different models. For each pollutant, eleven estimators are run on Stata for every country's regions (11 models × 3 pollutants × 5 countries), providing us a wide series of outputs, but only the most significant ones will be presented.

The econometric analysis begins with the panel unit root test, adopting Levin-Lin-Chu's (Levin et al. 2002), to check the stationarity of the data to avoid spurious regressions. The cointegration test for every nation will be analyzed afterward to check the long-run relationship between all the variables. For this purpose, the Pedroni cointegration test is selected (Pedroni 2004).

Once confirmed the cointegration relationship, each country's situation will be then discussed through the estimations' analysis. The pooled OLS estimator model is selected for all the pollutants (NOx, PM10, and PM2.5) throughout all the countries (Sayrs 1989). This model is chosen due to its higher *R*-squared compared to other models, for the majority of the variables in every nation. Moreover, having one common model is useful in terms of comparisons and provides a more accurate analysis among the panels. Whenever the pooled OLS estimator cannot appropriately describe the relationship among the variables and the pollutants, other models are explored, to complement the first one and/or confirm its results. The models employed vary across the nations according to the significance they present in explaining the variables: for Portugal and France, the random-effects estimator is mainly adopted, whereas for Italy, the fixed-effects estimator is employed. For Spain and Greece, no specific second estimator is used for all the independent variables, as will be seen later on.

After these estimations, the Granger causality test is conducted throughout the five countries' regions. The Dumitrescu–Hurlin panel Granger causality test is selected for this purpose (Dumitrescu and Hurlin 2012). This test suggests whether a short-run causal relationship exists among the variables, as the long-run relationships between them are explored with the cointegration test.

Empirical results

Panel unit root test

The study checks the stationarity of the variables by applying the Levin-Lin-Chu unit-root test to all the variables. Table 5 shows the panel unit root test's results for all five countries. The panel time series should report the stationary property to have economically meaningful and reliable estimates of the explanatory variables.

As some of these panel data contain unit roots at their levels, the test is run again on these variables' first differences. Whenever the level variable's *p* value is high, therefore significantly confirming that the panels are stationary, the first difference is not necessary. Overall, all the variables in all the countries' panels have proven to be stationary, therefore leading us to accept the alternative hypothesis of no unit root.

Panel cointegration test

Once confirmed the stationarity of the variables, the Pedroni panel cointegration test is selected to check whether these are integrated into all of the five countries. The null hypothesis represents no cointegration, while the alternative one shows that the variables are cointegrated. The results of the test are outlined in Table 6, and they show that the null hypothesis can be rejected at the 1% significance level, suggesting that the variables are integrated for all the three air pollutants in each of the five countries. This confirms the long-run relationship among NOx, PM10, and PM2.5 emissions, economic growth, tourism, and energy consumption in the French, Spanish, Greek, Portuguese, and Italian regions.

Pooled OLS estimation

The pooled OLS estimator is applied to check what relationships exist among the variables within the panel time-series

Table 5 Levin-Lin-Chu unit-root test

France LLC test				
Variables	**Level**	***p* value**	**First-difference**	***p* value**
GDP	−17.056	0.000	-	-
GDP2	−17.056	0.000	-	-
TOUFO	−4.236	0.000	-	-
TOURE	0.695	0.756	−22.265	0.000
ENE	−14.642	0.000	-	-
Nox	3.848	0.999	−8.615	0.000
PM10	−14.874	0.000	-	-
PM2.5	−12.796	0.000	-	-
Spain LLC test				
Variables	**Level**	***p* value**	**First-difference**	***p* value**
GDP	−10.318	0.000	-	-
GDP2	−10.318	0.000	-	-
TOUFO	−7.392	0.000	-	-
TOURE	−16.937	0.000	-	-
ENE	−16.686	0.000	-	-
Nox	−3.529	0.000	-	-
PM10	1.138	0.872	−8.246	0.000
PM2.5	3.794	0.999	−3.784	0.000
Greece LLC test				
Variables	**Level**	***p* value**	**First-difference**	***p* value**
GDP	−16.886	0.000	-	-
GDP2	−16.886	0.000	-	-
TOUFO	−6.357	0.000	-	-
TOURE	−9.273	0.000	-	-
ENE	−6.514	0.000	-	-
NOx	−7.614	0.000	-	-
PM10	−19.779	0.000	-	-
PM2.5	−7.007	0.000	-	-
Portugal LLC test				
Variables	**Level**	***p* value**	**First-difference**	***p* value**
GDP	−8.355	0.000	-	-
GDP2	−8.355	0.000	-	-
TOUFO	−6.845	0.000	-	-
TOURE	−4.061	0.000	-	-
ENE	−2.363	0.009	-	-
NOx	7.513	1.000	−6.755	0.000
PM10	−2.136	0.016	-	-
PM2.5	−1.939	0.026	−2.383	0.009
Italy LLC test				
Variables	**Level**	***p* value**	**First-difference**	***p* value**
GDP	−5.266	0.000	-	-
GDP2	−5.266	0.000	-	-
TOUFO	−8.948	0.000	-	-
TOURE	−5.026	0.000	-	-
ENE	−5.252	0.000	-	-
NOx	−15.388	0.000	-	-
PM10	−40.022	0.000	-	-
PM2.5	−38.813	0.000	-	-

data. Table 7 provides the results only for the economic variables under consideration: GDP and GDP2, to see whether there is evidence that confirms the EKC existence. Later, the other explanatory variables included in the model will be outlined singularly for each country.

The results show that there is no evidence of tourism-induced Environmental Kuznets Curve between per capita GDP and the three per capita pollutants for any of the five countries' regions.

Portuguese, Italian, and Greek regions present a decreasing relationship between economic growth and air pollution. Instead, Spanish regions show a positive relationship, even though the Spanish economic variables from this model are not appropriate at explaining their relationship with the NOx and PM2.5 emissions, as the high *p* values show. Finally, mixed evidence is found for the French regions, whose NOx and PM2.5 emissions appear to increase as the economy grows, while PM10 decreases.

These five countries score very high in the Environmental Performance Index (EPI) ranking.[3] The EPI index provides a national scale instrument of how close countries are to incorporating environmental policy goals. The EPI takes into account 24 performance indicators across 10 issues categories covering environmental health and ecosystem vitality. The 2018 EPI ranks France, Spain, Italy, Greece, and Portugal in places number 2, 12, 16, 18, and 21 out of 180 countries. Even so, at a regional level, there is still not much evidence that good environmental performance can be achieved, as Table 7 reports.

France

Through the pooled OLS estimator, no Environmental Kuznets Curve for the French regions has appeared from the analysis as shown in Table 8, instead, mixed evidence has arisen: there is a positive relationship between economic growth and NOx and PM2.5 emissions, whereas there's a negative correlation between the economic variables and the PM10 pollutant.

Normally, we would expect energy consumption to have a positive relationship with all of the pollutants. Instead, from the outputs, it is noticeable that the energy variable for the French regions also has mixed results: a 1% increase in energy use increases by 4% and by about 1% the emissions of NOx and PM2.5, respectively, while reduces by 2% the PM10 emissions.

Moreover, mixed evidence is also found for the tourism variables. A 1% increase in foreign tourists' visits increases PM10 emissions by 0.23%. The same increment in domestic

[3] Environmental Performance Index 2018: https://epi.yale.edu/downloads/epi2018policymakerssummaryv01.pdf

Table 6 Pedroni cointegration test

France	NOx		PM10		PM2.5	
	Statistic	*p* value	Statistic	*p* value	Statistic	*p* value
Modified Phillips-Perron t	6.6821	0.000	6.8374	0.000	6.9077	0.000
Phillips-Perron t	−9.4555	0.000	−8.0638	0.000	−6.3760	0.000
Augmented Dickey-Fuller t	−13.8314	0.000	−10.5289	0.000	−9.2244	0.000
Spain	**NOx**		**PM10**		**PM2.5**	
	Statistic	*p* value	Statistic	*p* value	Statistic	*p* value
Modified Phillips-Perron t	6.5774	0.000	6.4595	0.000	6.5224	0.000
Phillips-Perron t	−22.1545	0.000	−23.7663	0.000	−20.2101	0.000
Augmented Dickey-Fuller t	−16.0282	0.000	−16.4415	0.000	−15.6800	0.000
Greece	**NOx**		**PM10**		**PM2.5**	
	Statistic	*p* value	Statistic	*p* value	Statistic	*p* value
Modified Phillips-Perron t	5.2092	0.000	5.6276	0.000	5.7840	0.000
Phillips-Perron t	−18.0225	0.000	−9.9725	0.000	−9.4333	0.000
Augmented Dickey-Fuller t	−16.5256	0.000	−6.2333	0.000	−5.8502	0.000
Portugal	**NOx**		**PM10**		**PM2.5**	
	Statistic	*p* value	Statistic	*p* value	Statistic	*p* value
Modified Phillips-Perron t	3.8672	0.000	3.6606	0.000	3.3330	0.000
Phillips-Perron t	−6.2444	0.000	−17.7314	0.000	−24.0631	0.000
Augmented Dickey-Fuller t	−3.5985	0.000	−9.5258	0.000	−14.9823	0.000
Italy	**NOx**		**PM10**		**PM2.5**	
	Statistic	*p* value	Statistic	*p* value	Statistic	*p* value
Modified Phillips-Perron t	7.2258	0.000	6.8098	0.000	6.8042	0.000
Phillips-Perron t	−16.9781	0.000	−9.9407	0.000	−10.5003	0.000
Augmented Dickey-Fuller t	−12.7504	0.000	−16.2453	0.000	−17.2349	0.000

Table 7 Pooled OLS estimator economic outputs

	NOx			**PM 10**			**PM 2.5**		
		Coef	***p* value**		**Coef**	***p* value**		**Coef**	***p* value**
France	GDP	36.236	0.008	GDP	−73.066	0.000	GDP	3.073	0.245
	GDP2	5.7248	0.006	GDP2	−10.849	0.000	GDP2	0.752	0.068
		Coef	***p* value**		**Coef**	***p* value**		**Coef**	***p* value**
Spain	GDP	0.675	0.928	GDP	14.534	0.039	GDP	2.514	0.681
	GDP2	0.125	0.899	GDP2	2.030	0.030	GDP2	0.412	0.611
		Coef	***p* value**		**Coef**	***p* value**		**Coef**	***p* value**
Greece	GDP	−53.156	0.001	GDP	−29.150	0.018	GDP	−34.520	0.005
	GDP2	−6.645	0.001	GDP2	−3.705	0.015	GDP2	−4.287	0.004
		Coef	***p* value**		**Coef**	***p* value**		**Coef**	***p* value**
Portugal	GDP	−51.029	0.068	GDP	−49.637	0.017	GDP	−56.700	0.011
	GDP2	−6.412	0.068	GDP2	−6.118	0.019	GDP2	−6.970	0.012
		Coef	***p* value**		**Coef**	***p* value**		**Coef**	***p* value**
Italy	GDP	−4.369	0.000	GDP	−3.836	0.000	GDP	−3.621	0.001
	GDP2	−0.769	0.000	GDP2	−0.719	0.000	GDP2	−0.680	0.000

tourists decreases the same pollutant's emissions by 0.26%. Instead, the opposite trend is found for the NOx and PM2.5 emissions, provided a 1% increase in foreign tourists decreases the emissions by around 0.17%, while the same amount of emissions increase when a 1% increase in French visitors is considered. Summing up, an inverse pattern for the emissions of PM10 is revealed compared to the other two pollutants, regarding their relationship with all the variables employed in the analysis: economic, tourism, and energy.

Another test has been conducted to confirm the evidence found with the previous model and to fill what was left unclear. The random-effects estimator has been chosen due

Table 8 Pooled OLS estimator outputs for France

	NOx			**PM 10**			**PM 2.5**		
		Coef	***p* value**		**Coef**	***p* value**		**Coef**	***p* value**
France	GDP	36.236	0.008	GDP	−73.066	0.000	GDP	3.073	0.245
	GDP2	5.725	0.006	GDP2	−10.850	0.000	GDP2	0.752	0.068
	TOUFO	−0.184	0.434	TOUFO	0.231	0.194	TOUFO	−0.165	0.003
	TOURE	0.187	0.426	TOURE	−0.260	0.147	TOURE	0.155	0.005
	ENE	4.018	0.008	ENE	−2.044	0.056	ENE	0.967	0.003
	R-squared		0.8398	*R*-squared		0.9510	*R*-squared		0.9947
	Adjusted *R*-squared		0.7953	Adjusted *R*-squared		0.9374	Adjusted *R*-squared		0.9932

Table 9 Pooled OLS estimator outputs for Spain

	NOx			PM 10			PM 2.5		
		Coef	*p* value		Coef	*p* value		Coef	*p* value
Spain	GDP	0.675	0.928	GDP	14.534	0.039	GDP	2.514	0.681
	GDP2	0.125	0.899	GDP2	2.030	0.030	GDP2	0.412	0.611
	TOUFO	−0.326	0.000	TOUFO	−0.473	0.000	TOUFO	−0.412	0.000
	TOURE	0.545	0.000	TOURE	0.748	0.000	TOURE	0.649	0.000
	ENE	0.881	0.000	ENE	0.873	0.000	ENE	0.885	0.000
		R-squared	0.6366		*R*-squared	0.7709		*R*-squared	0.7853
	Adjusted *R*-squared		0.6256	Adjusted *R*-squared		0.7639	Adjusted *R*-squared		0.7788

to the good degree of explanation of the pollutants (over 95% as Adjusted *R*-squared for the particulate matter, and 80% for NOx). Overall, this model's results coincide with the ones of the pooled OLS one for what concerns all the variables.

Spain

The outputs for the Spanish regions obtained from the pooled OLS estimator (Table 9) show that the foreign visitors appear to have an inverse relationship with NOx, PM10, and PM: an increase in their presence leads to a decrease in emissions. Conversely, an increment in Spanish tourists leads to an increase in atmospheric pollution for all three pollutants. The increment of the emissions is greater compared to the diminishing of the same ones when the number of tourists (domestic and foreign, respectively) increases.

High significance is presented for the tourism variables and energy consumption. As expected, a positive relationship is found among these variables: an increase of 1% in the use of energy leads to an increment of emissions by around 0.88% for the three pollutants with the pooled OLS model.

What is not well represented by this model are the economic variables, and this is the reason why other estimators have been analyzed: of the eleven econometric models considered in the study, none of them could perfectly describe these variables for the NOx emissions due to the low significance resulted by the high *p* values; instead, some estimators could do it for the particulate matter emissions, presenting a negative relationship between them and GDP and GDP2 for the Spanish regions.

Greece

As already stated, no regional EKC is found for Greece over the years 2009–2018 using the pooled OLS estimator. As Table 10 shows, the degree to which the input variables explain the variation of the pollutant is not high, particularly for the NOx emissions, which present an Adjusted *R*-squared of 40%.

Mixed results regarding the effect of tourism on air pollutants are documented. The venue of foreign tourists appears to exert a negative impact on all of the three pollutants: an increase of 1% leads to a decrease of 0.26%, 0.50%, and 0.43% in NOx, PM10, and PM2.5 emissions, respectively; in contrast, an increase of domestic visitors raises the emissions of pollutants by approximately 0.27% for NOx and PM2.5, and around 0.33% for the PM10 ones.

Besides, we fail to record a consistently positive impact of energy consumption on the various pollutants: 1% increase in energy use decreases NOx emissions by 0.48%. A positive impact is surely seen for the PM10, for which a 1% increment in energy consumption leads to a 0.35% increase in emissions. Regarding the PM2.5, the model shows a positive impact of the energy variable on the pollutant, but the

Table 10 Pooled OLS estimator outputs for Greece

	NOx			PM 10			PM 2.5		
		Coef	*p* value		Coef	*p* value		Coef	*p* value
Greece	GDP	−53.156	0.001	GDP	−29.150	0.018	GDP	−34.520	0.005
	GDP2	−6.645	0.001	GDP2	−3.705	0.015	GDP2	−4.287	0.004
	TOUFO	−0.265	0.001	TOUFO	−0.498	0.000	TOUFO	−0.429	0.000
	TOURE	0.263	0.153	TOURE	0.326	0.029	TOURE	0.276	0.055
	ENE	−0.476	0.092	ENE	0.350	0.120	ENE	0.003	0.988
		R-squared	0.4866		*R*-squared	0.7811		*R*-squared	0.7238
	Adjusted *R*-squared		0.4173	Adjusted *R*-squared		0.7515	Adjusted *R*-squared		0.6864

Table 11 Pooled OLS estimator outputs for Portugal

	NOx			PM 10			PM 2.5		
		Coef	*p* value		Coef	*p* value		Coef	*p* value
Portugal	GDP	−51.029	0.068	GDP	−49.637	0.017	GDP	−56.699	0.011
	GDP2	−6.412	0.068	GDP2	−6.118	0.019	GDP2	−6.970	0.012
	TOUFO	−0.122	0.548	TOUFO	0.021	0.887	TOUFO	0.110	0.487
	TOURE	−2.063	0.000	TOURE	−1.844	0.000	TOURE	−2.051	0.000
	ENE	6.644	0.000	ENE	5.346	0.000	ENE	5.631	0.000
		R-squared	0.9701		*R*-squared	0.9752		*R*-squared	0.9736
	Adjusted *R*-squared		0.9667	Adjusted *R*-squared		0.9723	Adjusted *R*-squared		0.9706

very low significance requests us to check it with another estimator: the Linear Regression Model, which appeared to be better at describing the PM2.5 pollutant through the energy variable (low *p* value) confirming a positive impact: a 1% increase in energy use increases PM2.5 emissions by 0.46%. Summing up, for the Greek regions, energy usage increases the emissions of particulate matter but decreases the NOx's releases.

Portugal

For the Portuguese regions, the pooled OLS estimator shows an overall good significance: the goodness of the fit is provided by the consistent Adjusted *R*-squared of 97% over the three pollutants (Table 11). Only the foreign tourists' variable is found to be not appropriate at describing its impact on any of the three pollutants. Instead, the domestic tourists seem to negatively influence the emissions, given that an increase of 1% in Portuguese tourists decreases by approximately 2% the level of emissions in Portugal's regions.

Moreover, a positive and strong impact of energy consumption on the air pollutants is found, since a 1% increase in energy usage leads to a rise of 6.64% of NOx emissions and an average of 5.50% increase of particulate matter ones. This implies that Portugal should go in the direction of working on energy efficiency plans, to provide more energy-efficient technologies to its country's activities and industries, to mitigate air pollution and its consequences.

The same outputs appear using the random-effects estimator, whose significance at explaining the dependent variables is a bit superior to the previous model, and the Adjusted *R*-squared too. It confirms what the pooled OLS estimator has demonstrated: the consistently positive impact of energy on the emissions, a negative effect of domestic tourists on them, and mixed evidence for the foreign tourists variable, which, again, appears to be not good at explaining the pollutants. For this reason, other models have been selected to explain and give evidence of what is the effect foreign tourists have on the regional environment.

The estimators selected for analyzing the foreign tourism variable's behavior are the population-averaged, the fixed effects, the first-differences, and the linear regression ones. Their outputs are all suitable for explaining the foreign tourism-pollution relationship, as their very low *p* values demonstrate. For Portugal, a negative impact on all the three pollutants from both types of tourists (foreign and local) appears. The greatest reduction in terms of pollution is seen for the NOx emissions, around 0.30% for any 1% increase in foreign tourists. For the same visitors' increase, the PM10 emissions are reduced by around 0.16%, while the PM2.5 emissions decline by only 0.06%, consistently across all the four models.

Table 12 Pooled OLS estimator outputs for Italy

	NOx			PM 10			PM 2.5		
		Coef	*p* value		Coef	*p* value		Coef	*p* value
Italy	GDP	−4.369	0.000	GDP	−3.836	0.000	GDP	−3.621	0.001
	GDP2	−0.769	0.000	GDP2	−0.719	0.000	GDP2	−0.680	0.000
	TOUFO	−0.357	0.000	TOUFO	−0.417	0.000	TOUFO	−0.359	0.000
	TOURE	0.301	0.000	TOURE	0.410	0.000	TOURE	0.382	0.000
	ENE	0.011	0.740	ENE	0.036	0.308	ENE	0.031	0.381
		R-squared	0.4134		*R*-squared	0.4614		*R*-squared	0.4341
	Adjusted *R*-squared		0.3982	Adjusted *R*-squared		0.4475	Adjusted *R*-squared		0.4195

Italy

The pooled OLS estimator for Italy explains only 40–45% of the variation of the outputs by the other variables in the model, as outlined in Table 12. Even though, the variables are significant for each pollutant, except for the energy variable. This is the reason why a second model has been adopted to counter-check the conclusions drawn with the pooled OLS one, the fixed effects estimator.

Both models show a negative impact of foreign tourists on all of the three pollutants emissions, even though this effect is greater with the fixed effects estimator's outputs when comparing the single pollutants. The opposite happens for the domestic tourists: a rise in their arrivals leads to an increase in the air pollutants emissions and, this time, the magnitude of the effect is greater with the pooled OLS model.

No evidence of an Environmental Kuznets Curve appears for the Italian regions, as already mentioned. However, even though there is a negative relationship between economic growth and pollutants emissions, overall, the energy consumption increases the number of emissions released, as normally expected. Other models have been employed to check what is the actual effect of this variable on atmospheric pollution: population-averaged, random effects, dynamic panel, Linear regression. All of them confirm what has been concluded with the previous model: a positive impact is seen on the particulate matter emissions, while a negative one is confirmed for the NOx emissions. To notice is that both the effects (positive and negative) are not significant: a 1% increase in energy consumption makes a change in the air pollutant's emissions from 0.001% until a maximum of 0.01%.

Dumitrescu–Hurlin panel Granger causality test

To examine the causal relationship among pollutants' emissions, economic growth, foreign and local tourism, and energy consumption in a panel context, the Granger causality test is employed; specifically, the Dumitrescu–Hurlin panel Granger causality test is adopted in this analysis. The null hypothesis supports the inexistence of Granger causality for all the variables, whereas the alternative hypothesis assumes that there is at least one causal relationship in the panel data. Its interpretation allows detecting whether two variables influence each other (bidirectional relationship) or only univocally (unidirectional relationship).

Starting with the French regions, the outputs show that there is strong evidence to support bidirectional causality between all the three pollutants (NOx, PM10, and PM2.5) and both foreign and local tourism. This latter, though, is an exception since it does not present any causal link running to the NOx pollutant, while it is seen that NOx emissions influence the tourism made by French people. These one-way relationships may imply that the country implements extreme environmental policies towards incoming tourists, maybe through higher tourists' taxes for their expected exploitation of the country's finite resources, which could also lead to a crowding-out effect, with all its negative consequences.

Regarding Spain, the Granger causality test for its regions reveals evidence of bidirectional causality between the three pollutants and the variables of tourism made both by foreign and resident people. Therefore, foreign and domestic tourism affects the emissions, while at the same time it is also influenced by them. Tourism's impact on the Spanish air quality cannot be ignored, but the reverse also holds: they are both significant at explaining each other's behaviors. These findings demonstrate that tourism is not only a contributor to environmental pollution (especially atmospheric pollution) but also a victim of it.

For the Greek regions, instead, the outputs do not report any bidirectional causality among the variables. A one-directional causal relationship is detected from the three pollutants to both the tourism categories, except for the PM2.5 emissions which present no causality link at all, either with domestic or foreign tourism. These one-way relationships reveal that air quality and environmental policies may affect tourism development, but not vice versa.

The results show that air quality has important effects on tourism; therefore, local authorities should establish effective methods to improve air quality, to avoid big losses due to tourism demand's decline. Conversely, for the Greek case, the influence of the tourism sector on the environment is not highly significant, implying that the number of tourists is not a considerable determinant of air pollution.

In the Portuguese panel, significant unidirectional causality is revealed from the NOx and PM10 pollutants to both the typologies of tourism. Regarding PM10 emissions, they are also affected by foreign tourism (bidirectional causality), while they are not influenced by the local ones. In addition, bidirectional causality is found between PM2.5 and both foreign and domestic tourism, even though domestic tourism has weak evidence of influence on the pollutant. The fundamental would be to inspect the influences of any changes in atmospheric conditions on tourism demand, as it seems to be substantially affected by the country's air quality. In this case, the country's effort could be devoted to taking action to protect Portugal's image from potential damage caused by air pollution and promoting future sustainability strategies.

Regarding the Italian regions, foreign tourism growth shows to strongly influence all of the three pollutants. This means that tourism has statistically significant effects on the environment, whereas the influences of air pollution on tourism are significant only concerning NOx emissions. In fact, for the NOx emissions, bidirectional causality is found between them and both tourism categories, provided foreign and domestic tourism impacts and are affected only by NOx. Tourism's effect on the pollutants requires attention, as it indicates necessary measures and regulations to be applied, to lead towards the achievement of sustainable, more aware tourism. Finally, regarding PM10 and PM2.5 emissions, no significant causalities were found running from these pollutants to both domestic and foreign tourism.

Discussion and policy recommendations

Our results can be related to the existing literature, in some cases confirming their results, in others with opposite results. For instance, our findings fail to document any evidence supporting the tourism-induced EKC hypothesis for any of the air pollution variables at a regional level. No relationship between air quality degradation and economic growth, driven by tourism demand for the period, has been revealed, confirming what existent literature about regional studies has previously shown (Chan et al. 2020; Zhang et al. 2016). The research which included the pollutants employed in the present study (namely NOx, PM10, and PM2.5) did not even confirm the EKC at a national level (Gao and Zhang 2021).

Results do not coincide with those of De Vita et al. (2015). The authors validate the EKC hypothesis in Turkey, concluding that despite the environmental degradation caused due to tourism development, policymakers should not protect the environment at the expense of tourism-led growth. At the regional level, our study suggests that tourism-growth policies should carefully balance the need to promote tourism development without leading to more environmental degradation, requiring the adoption of sustainable development principles in tourism development strategies. Our conclusion coincides with that of the work of Liu et al. (2019), in which it is stated that it is a priority to pursue tourism development while paying attention to its negative impact on air (environment) quality. Perhaps only the higher income regions allow to validate the EKC curve as the results of Ozturk et al. (2016) and Al-mulali et al. (2015) show at the national level, but this type of study would demand more data which is not currently available. Recently, Adedoyin et al. (2021) suggest that green economic growth is possible if appropriate environmental protection policies are pursued to limit the harmful impact of some economic activity sectors, not only those associated with the tourism industry, on environmental quality. Our results suggest the same but at a regional level, that as far as we are aware has not been studied yet.

One of our main results shows that there are differences in the impacts of international tourists and domestic tourists on air pollution. Foreign tourists negatively influence emissions, while domestic ones increase emissions. This result is clear for Spain, Greece, and Italy. Domestic tourism can raise air pollution, due for instance to the travel behaviors adopted, such as the kind of transport used to travel (often is a private car), in contrast with international tourists that seem to tend to adopt more pro-environmental travel behaviors, often using public transportation. This is mentioned in a study about 17 Chinese provinces, in which Liu et al. (2019) believe that highways have a greater impact on domestic tourists compared with railways, as these people are more likely to travel by car, while railways, compared with highways, have a greater impact on foreign visitors, as they tend to move by train.

It is not only tourism that presents impacts on the environment, but the quality of air also influences tourisms' flows, contradicting the conclusions of Lee et al. (2015), and confirming those of Dong et al. (2019): people are unwilling to travel to polluted destinations. Our empirical findings through the Granger causality test show causality not running exclusively from the pollutants to the categories of tourism, but also vice versa: France, Spain, and Portugal present causality running from all NOx, PM10, and PM2.5 emissions to both domestic and foreign tourism. For Greece, the same is valid, except for PM2.5 emissions' impact on local tourism, even though low significance due to the high

p value is observed for this specific case. Regarding Italy, at a regional level, our results show that NOx emissions have an impact on both categories of tourism, while particulate matter emissions do not (low significance is observed for both PM results).

These results can be relevant for policymakers and managers in the area of tourism, given that specific and targeted measures can be prepared for domestic and international tourists, to minimize the environmental impact of tourism in general. Specifically, strategies should be adopted to stimulate more sustainable behaviors by domestic tourists, such as the use of more environmentally friendly transportation, reduction of water and energy consumption, and recycling and reusing materials. Marketing strategies could also be developed to sensitize tourists, specifically domestic tourists, to the importance of adopting environmentally friendly behaviors. Concerning the negative impact on air quality of domestic tourists, there is also room for enhancing their environmental concern, as Theobald (2005) points, by strengthening among domestic tourists national feeling and a sense of pride in the natural and cultural heritage of the travelers' home country. Additionally, providing a very sense of national unity is useful for preventing regional fragmentation. According to the same author, as long as the individual characteristics and identity of the various regions are not lost, those trips can benefit both the visitors and the places visited.

Understanding the relationship between per capita emissions, economic growth, tourism, and energy consumption is significant for policy-makers and countries' governments. It is imperative to recognize the vital importance of the tourism sector to the regional economies and also its big negative impact on the environment. Overall, the tourism industry should be reinforced and improved at all levels of government, promoting sustainable tourism policies at a global and regional scale, through which the preservation and conservation of environmental resources should be attained.

Besides the weak (or no-) correlation found, tourism's impacts on the environment should be taken into account in the policy formulation process. The policy-makers strategy needs to include raising awareness about issues related to the environment, promoting its protection, and encouraging the adoption of best practices among all players in the tourism industry.

Efforts should be made to offset the negative impacts resulting from the expansion of the tourism sector. It is fundamental to review the current tourism-related environmental policies, laws, and regulations, complementing and modifying them if necessary. Well-planned, coordinated strategies and clear guidelines for tourism development and emissions reduction should be implemented. Furthermore, a transformation from carbon-intensive tourism into green sustainable tourism should be pursued (Adedoyin et al. 2021). Execution of energy efficiency programs should be pursued, along with the implementation of incentives and financial support for the use of renewable energy at the regional level to reduce the emissions impact. Renewable energy sources could be regarded as an attractive element in the tourism industry, in some cases even leading to an increase in the number of tourists due to their modern design and eco-image (Beer et al. 2018).

Indeed, tourism policies should foster environmental protection at different levels, as for instance pointed by Campón-Cerro et al. (2020) for water resources. The role of environmental policies should be that of pursuing the sustainability objective at all levels of development, including the adoption of best practices to invest in tourists' education, which will increase their sensibilization towards environmental problems and enable them to behave responsibly.

Conclusions

The objective of this study was to investigate the relationship between air pollution, economic growth, tourism, and energy consumption using data of five European countries among the main touristic destinations (namely France, Spain, Greece, Portugal, and Italy) on a regional scale, considering the study period from 2008 to 2019. A panel for each country was created, and panel modeling techniques were employed for each.

The most important result achieved through this empirical work is that the tourism EKC hypothesis is not validated at the regional level. The results point out that tourism development has different impacts (both positive and negative) on the different air pollutants across the countries. France presents mixed evidence; therefore, no precise trend can be deduced for either kind of effect. Spain, Greece, Portugal, and Italy present a common pattern since whenever the number of foreign tourists increases, the level of emissions falls. For Spain and Greece, PM10 is the pollutant that presents the greatest reduction, followed by PM2.5 and lastly by NOx; for Portugal, the NOx is the pollutant whose emissions get reduced the most, followed by PM10 and PM2.5. The Italian case, instead, reports slight differences according to the estimator employed.

For Spain, Greece, and Italy, an increment of emissions appears whenever a rise in domestic tourists is recorded. Spain and Greece show again the same order as before: the emissions that have the greatest change (this time incremental) are PM10, followed by PM2.5 and then NOx. Even though Italian tourists appear to increase the country's emissions, different models present unalike data. The pooled OLS estimator shows how PM10 increases the most and NOx the least; respectively, the fixed effects estimator has the NOx and the PM2.5 ones. Portugal, instead, shows

again a decline in emissions, even when the percentage of domestic tourists increases. The NOx emissions are still the ones that get reduced the most, this time followed by PM2.5 and then PM10.

Despite this study's characteristic of exploring what is not yet widespread in the literature, there are some limitations associated with it. Firstly, the analysis is based on emissions estimates, since there are no observations or measurements for this type of variable. Besides that, the analysis focused only on the most critical pollutants in urban areas, and do not include the entire set of atmospheric pollutants (like CO, SO_2, NH_3, etc.). Forthcoming studies could consider the use of alternative ways of measuring the emissions, not only per capita but, for example, as the country's total emissions or emissions intensity on GDP/unit. Moreover, the analysis could be expanded beyond air quality investigation. It could employ different environmental degradation indicators which are not emissions, such as municipal waste, lack of urban sanitation, and dissolved oxygen in rivers. Data about environmental indicators is still a controversial issue due to the difficulty in collecting the data itself, therefore leading to distortions, whose importance cannot be neglected. These distortions can also appear as a result of the sample's selection, since most of the time the monitoring stations are located where the pollution is more intense, resulting in an overestimation of it. Additionally, the tourism industry involves multiple activities, each of which with different impacts on the various air pollutants. Thus, managers within the tourism industry should bear in mind the different implications and the local specificities to ensure the correct management of tourism resources and guarantee that tourism demand will not decrease in face of air pollution episodes, only possible if all involved agents learn to live sustainably.

Future works may focus on differentiating the negative impact of tourism according to the different sources of environmental pollution that are responsible for it. Regarding the econometric techniques, checking the cross-sectional dependence, before performing the panel data analysis, could be appropriate to investigate whether the observations in the series are correlated with each other, which could result in more accurate outcomes. Finally, other periods can be studied and comparisons among the different stages conducted, to highlight the results' differences through time and explore the reasons that justify the outputs (for example due to new environmental policies and rules). Particularly, studies using data before and after COVID pandemia should be used when available, as this new context modified the way tourism is faced, concerning for instance environmental awareness, ways, and means of transport, or accommodation types.

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Declarations

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