Ben Jebli *et al. Lat Am Econ Rev (2019) 28:2*
https://doi.org/10.1186/s40503-019-0063-7

Latin American Economic Review

RESEARCH Open Access

The dynamic linkage between renewable energy, tourism, CO_2 emissions, economic growth, foreign direct investment, and trade

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Abstract

Because of the lack of econometric studies in relevance to the link between tourism and renewable energy, the goal of this study is to remedy this lack and to explore the causal relationships between renewable energy consumption, the number of tourist arrivals, the trade openness ratio, economic growth, foreign direct investment (FDI), and carbon dioxide (CO_2) emissions for a panel of 22 Central and South American countries, spanning the period 1995–2010. The empirical findings document that the variables under investigation are cointegrated. Short-run Granger causality tests illustrate unidirectional causalities running from: (i) renewable energy to CO_2 emissions and trade; (ii) tourism to trade and FDI; and (iii) economic growth to renewable energy and tourism. In the long run, there is evidence of bidirectional causality between renewable energy, tourism, FDI, trade, and emissions. Thus, renewable energy and tourism are in a strong long-run causal relationship. Moreover, long-run estimates for the whole panel and for the three income panel groups considered (Lower Middle, Upper Middle, High) highlight that tourism, renewable energy, and FDI contribute to the reduction of emissions, while trade and economic growth lead to higher carbon emissions. Therefore, attracting foreign direct investment, encouraging the use of renewable energy, and tourism development, particularly green tourism, are good policies for this region to combat climate change.

Keywords: Renewable energy, Tourism, Foreign direct investment, CO_2 emissions, Panel cointegration

Jel Classification: C33, F18, F21, O54, Q42, Z38

1 Introduction

Nowadays, tourism plays an important role in most countries as the number of international tourists has considerably expanded (United Nations Environment Program 2011). The tourism sector represents an important part of the world gross domestic product (GDP), employs directly and indirectly an important proportion of the global work force, represents an important share in total exports, and foreign direct investment (FDI) represents an important source of world's tourism investment. The expansion of this sector resulted in an increase in fossil energy consumption and in important green house gas (GHG) emissions. However, investments in energy efficiency and renewable energy related to the touristic sector seem generating significant returns within a short payback period. In addition, a great proportion of travelers are found to promote environmentally friendly tourism and are willing to pay for related experiences (United Nations Environment Program 2011). All these reasons make studying the interaction of tourism with these economic variables, and particularly with renewable energy, worth considering. To the best of our knowledge, with the exception of the Ben Jebli et al. (2015a) study for Tunisia, no research has been implemented on the dynamic linkages between renewable energy and tourism. This paper attempts to remedy this lack of studies by investigating the interaction of tourism with renewable energy, economic growth, carbon dioxide (CO_2) emissions, FDI and international trade. To this end, the analysis employs data on a panel basis coming from Central and South American countries, while it focuses on the relationship between tourism and renewable energy.

Our sample is chosen from Central and South America because they are considered among the richest regions in biodiversity and renewable energy potential. Central America belongs to the Mesoamerican Biodiversity Hotspot and contains nearly 8% of the earth's biodiversity (Global Energy Network Institute 2012). In addition, it is a geologically active region with both earthquakes and volcanic eruptions usually happening, and 80% of it is mountainous, while the coastal areas are flat. These features make this region rich in renewable energy resources for electricity generation. Regional integration can help this region to move to 100% dependency on renewable energy for electricity generation, while increasing economic and energy security, decreasing dependency on foreign oil, developing greenly, and decreasing poverty (Global Energy Network Institute 2012).

This paper examines the causal link between renewable energy consumption, international tourist arrivals, trade openness ratio, economic growth, foreign direct investment, and CO_2 emissions by considering a panel composed of 22 Central and South American countries. We also estimate the long-run impact of renewable energy consumption, international tourist arrivals, trade, FDI, and GDP on CO_2 emissions. The paper is closely related to that by Ben Jebli et al. (2015a), but it differs from it on several aspects. First, in the current paper, we use panel methods, whereas in the previous paper, time series methods are used. For this purpose, the Pesaran (2004) cross-sectional dependence (CD) statistic, and the Pesaran (2007) and Smith et al. (2004) second-generation panel unit root tests are used. Second, in the current paper, the renewable energy consumption comprises all types of renewable resources, whereas in the previous paper, only combustible renewables and waste are considered. Third, in the current paper, we add international trade and FDI variables that were not there before.

This study is organized as follows: Sect. 2 gives an idea about tourism and renewable energy in the world. Section 3 is a literature review, while Sect. 4 is concerned with data presentation and empirical methodology description. Section 5 is designated for long-run parameters estimates, while Sect. 6 reports Granger causality. Finally, Sect. 7 concludes the paper with policy recommendations.

2 Tourism and renewable energy

Tourism plays an important role nowadays in most countries, where 935 million international tourists were recorded in 2010 (United Nations Environment Program 2011). The tourism economy represents 5% of the world GDP and accounts for 6–7% of total employment. With a 6% share of total exports, international tourism is ranked fourth in world exports after fuels, chemicals and automotive products. For 60 countries, tourism is the first export sector, while for over than 150 countries, it is among the five top export sectors. Tourism is the principal source of foreign exchange for 33% of developing countries and for 50% of least developed countries. It employs directly and indirectly 8% of the global workforce; while one job in the core tourism industry generates nearly one and a half additional indirect jobs (United Nations Environment Program 2011). Tourism is an important sector in the economies of Central and South America. According to the World Travel & Tourism Council (2018), the total contribution of the travel and tourism sector to GDP in Latin America was 8.6% in 2017, and is estimated to rise by 3.2% per annum to reach 9.1% in 2028. The total contribution of this sector to employment, including indirect jobs, was 7.6% in 2017 and is expected to rise by 2.0% per annum to reach 8.3% in 2028. Tourism exports generated 7.2% of total exports in 2017 and are predicted to grow by 5.3% per annum to reach 9.0% in 2028. The investment in this sector represented 6.2% of total investment in 2017 and is expected to grow by 4.1% per annum to attain 6.5% in 2028.

The rapid growth in both international and domestic travel, the trends to travel over shorter periods of time and further, and the focus on energy-intensive transportation all increase the non-renewable energy dependence of tourism, resulting in a 5% contribution of the sector to global GHG emissions. Other challenges include excessive water consumption in relation to residential water use, untreated water discharge, waste generation and damage to local terrestrial and marine biodiversity. Investments in energy efficiency and renewable energy have been found to generate significant returns in a short payback period. Improved waste management should help tourism businesses save money, create more jobs and improve destination attractiveness (United Nations Environment Program 2011).

According to the United Nations Environment Program (2011), sustainable tourism refers to tourism activities that can be maintained indefinitely in their economic, social, cultural, and environmental contexts. Thus, it is not a special form of tourism, but rather all forms of tourism may strive to be more sustainable. Ecotourism refers to a segment within the tourism sector focusing on environmental sustainability. This implies that ecotourism aspires to be protecting the environment with more energy efficiency and renewable energy use. Traditional mass tourism has reached a steady growth stage. On the other hand, ecotourism, nature, heritage, culture and 'soft adventure' tourism take the lead and are expected to grow rapidly over the next two decades. Global spending on ecotourism is estimated to increase about six times the growth rate of the tourism industry.

Public spending on public goods, such as waste management and renewable energy infrastructure can reduce the cost of green private sector investment in green tourism. Governments can also use tax breaks and subsidies to encourage private investments in green tourism. Time-limited subsidies may be granted, for example, to the purchase of equipment or technologies that reduce waste, promote energy efficiency or the use of renewable energy. At the same time, the use of resources and energy, as well as the production of waste must be properly evaluated to reflect their real cost to society. The United Nations Environment Program (2011) recommends tourism promotion and marketing initiatives that emphasize sustainability as a core option. As the tourism industry is dominated by small- and medium-sized enterprises (SMEs), it is also essential to facilitate their access to decision support tools, information and knowledge, as well as capital. Partnership approaches aimed at reducing the costs and risks of financing sustainable tourism investments and supporting SMEs should be considered to facilitate the transition to green tourism activities.

Taking into account the United Nations Environment Program (2011) study, we can think that tourism promotes and supports environmentally friendly practices thus driving increases in the use of renewable energy because of the following reasons: (i) energy efficiency and a more intensive use of renewable resources are primordial for the sustainability and competitiveness of the tourism sector; (ii) sustainability considerations have an increasing influence on tourist choices. A survey conducted by Trip Advisor in 2007 on worldwide travelers concluded that 38% had stayed at an environmentally friendly hotel, while 34% were willing to pay more to stay in environmentally friendly hotels (Pollock 2007). In addition, a study conducted by SNV (2009) indicates that some 58.5 million US travelers would "pay more" for travel companies that strive to protect and preserve the environment. This pushed leading airlines to explore alternative fuel strategies; (iii) there is a growing trend within the tourism industry of investing in sustainability. These investments could be in energy efficient features and services, photovoltaic electricity, waste water re-use and rainwater recovery, and energy efficiency in sustainable construction and renovation projects. Such investments are driven mainly by increasing fossil fuel energy costs, possible pollution surcharges, increasing expectations of customers (particularly from Europe and North America) and, thus, those of operators and the entire supply chain, decreasing costs of renewable energy technologies, low-carbon technological advances, government incentives, ecological labels and/or standards, regulations and legislation on energy efficiency and sustainability in buildings; (iv) customers demand for clean destination and the pressure from major tour operators is likely to push local governments to improved solid waste management and the investment in sanitary landfills and solid waste recycling capacity which can enhance the consumption of renewable energy coming from solid waste.

Prinsloo (2015) explores whether renewable energy is beneficial for tourism and focuses particularly on the environmental impact, consisting of the noise and/or sight or visual pollution, that might have renewable energy structures, i.e., buildings, civil or mechanical structures. He recommends that renewable energy structures must be erected and managed carefully not of being detrimental to the environment. There are bad feelings from residents in and around areas where renewable energy structures, such as wind turbines or solar panels, are erected. Nonetheless, eco-tourists see renewable energy structures as ethically and morally the correct thing to do. These tourists engage in improving the quality of the environment through their participation in tourism. Thus, renewable energy may have a positive impact on tourism.

3 Literature review

Our study is linked to the strand of the literature dealing with renewable energy consumption and tourism. There is a rich and interesting literature concerned by studying renewable energy consumption and its interactions with other interesting variables like pollution emissions, non-renewable energy consumption, international trade and gross domestic product (Al-mulali et al. 2014; Apergis and Payne 2010a, b, 2011, 2012, 2014; Ben Jebli and Ben Youssef 2015a, b; Ben Jebli et al. 2015b; Dogan 2016; Menegaki 2011; Menyah and Wolde-Rufael 2010; Ocal and Aslan 2013; Sadorsky 2009a, b; Shafiei and Salim 2014; Tugcu et al. 2012).

Sadorsky (2009b) considers a panel of 18 emerging countries and shows the absence of short- and long-run causal relationships between output and renewable energy consumption. However, in the long run, increasing output increases renewable energy consumption. Tugcu et al. (2012) compare renewable and non-renewable energy sources in the G7 countries (i.e., Canada, France, Germany, Italy, Japan, UK, and US) to decide which type of energy is more important for economic growth. In the case of a classical production function, they find bidirectional causality between economic growth, renewable and non-renewable energy consumption for all considered countries. Ocal and Aslan (2013) study the causal relationship between renewable energy consumption and output in Turkey. They document that renewable energy consumption has a negative impact on output, while they show the presence of unidirectional causality running from output to renewable energy consumption.

Al-Mulali et al. (2014) study the impact of renewable and non-renewable electricity consumption on economic growth by considering 18 Latin American countries. Their results highlight the presence of long-run bidirectional causality between economic growth, renewable and non-renewable electricity consumption, capital, labor, and trade. In addition, they show that renewable electricity consumption is more significant than non-renewable electricity consumption in promoting economic growth both in the short- and in the long run. Apergis and Payne (2014) explore the determinants of per capita renewable energy consumption for a panel of seven Central American countries. They show the presence of long-run cointegration between per capita renewable energy consumption, economic growth, carbon emissions, real coal prices, and real oil prices. Ben Jebli and Ben Youssef (2015b) consider a panel of 69 countries and show the presence of short-run unidirectional causality running from renewable energy consumption to trade (exports or imports). There is also long-run bidirectional causality between trade and renewable energy consumption. Long-run parameter estimates suggest that renewable energy consumption, non-renewable energy consumption, and trade have a beneficial impact on economic growth. Mert and Bölük (2016) examine the impact of FDI and renewable energy consumption on CO_2 emissions by considering an unbalanced panel of 21 Kyoto countries. In the long run, FDI and renewable energy consumption reduce carbon emissions. Thus, their findings support the "pollution haloes hypothesis" which states that FDI brings in cleaner technologies. However, the inverted U-shaped environmental Kuznets curve (EKC) hypothesis was not supported.

Our study is also related to the strand of the literature dealing with tourism. There is a growing literature concerned for tourism and its causal relationships with other economic variables, such as economic growth, energy consumption, CO_2 emissions, urbanization, and foreign direct investment (Balaguer and Cantavella-Jordá 2002; Belloumi 2010; Dogan et al. 2017; de Vita et al. 2015; Dristakis 2004; Gunduz and Hatemi-J 2005; Katircioglu 2009a, b, 2014a, b; Katircioglu et al. 2014; Lee and Brahmasrene 2013; Ozturk et al. 2016).

Katircioglu (2009a) investigates the tourism-led-growth (TLG) hypothesis for Turkey by employing the bounds test and Johansen approach for cointegration. He does not find any cointegration between tourism and economic growth, while he concludes that the TLG issue still deserves further attention from researchers for comparison purposes. Belloumi (2010) studies the relationship between tourism receipts, the real effective exchange rate, and GDP growth in Tunisia, spanning the period 1970–2007. He shows the presence of long-run unidirectional causality running from tourism receipts to economic growth. In addition, increasing tourism receipts increase GDP in the long run. Finally, he suggests that a policy relying on tourism to generate economic growth seems to be convenient for Tunisia.

Lee and Brahmasrene (2013) consider a panel of 27 nations of the European Union (EU) and use panel cointegration method and fixed-effect models to investigate the presence of long-run equilibrium among tourism, carbon dioxide emissions, GDP, and foreign direct investment. Increasing tourism, emissions, and FDI increase output. In addition, increasing GDP leads to higher CO_2 emissions, while increasing tourism and FDI reduce CO_2 emissions. They conclude that when policy-makers make important efforts to attract international tourists, for instance through marketing campaigns, both the economy and the environment benefit. De Vita et al. (2015) find that international tourist arrivals, GDP, squared GDP, energy consumption, and CO_2 emissions cointegrate for the case of Turkey. In the long run, tourist arrivals, GDP, and energy consumption have a positive impact on CO_2 emissions, while the inverted U-shaped EKC hypothesis is supported. They suggest that despite the environmental deterioration coming from more tourism, policies aimed at environmental protection should not be conducted at the expense of TLG.

Dogan et al. (2017) explore the long-run dynamic relationship between CO_2 emissions, GDP, the square of GDP, energy consumption, trade openness, and tourism for the case of Organization for Economic Co-operation and Development (OECD) countries. In the long run, increasing energy consumption or tourism increases CO_2 emissions, while increases in trade openness lead to environmental improvements. They show the presence of unidirectional causality running from tourism to CO_2 emissions, energy consumption, and trade, and from GDP to tourism. They recommend to OECD policy-makers to impose policies in favor of environmental protection and to encourage the use of cleaner technologies in the tourism sector. Ozturk et al. (2016) examine the EKC hypothesis using the ecological footprint as an ecological indicator and GDP from tourism as an economic indicator. They establish an environmental degradation model for 144 countries. They show that the number of countries having a negative relationship between the ecological footprint and its determinants (i.e., tourism, energy, trade, and urbanization) is relatively more important in the upper-middle- and high-income countries. In addition, the inverted U-shaped EKC hypothesis is more present in the upper-middle- and high-income countries. They recommend implementing ecological footprint and taxes for energy conservation in the tourism sector to reduce the tourism environmental pressure.

To the best of our knowledge, Ben Jebli et al. (2015a) was the first paper studying the dynamic causal relationships between tourism and renewable energy consumption, more precisely combustible renewables and waste consumption. They employ the autoregressive distributed lag (ARDL) approach to investigate the causal relationship between GDP, combustible renewables and waste (CRW) consumption, CO_2 emissions, and international tourism for the case of Tunisia. They show the presence of short-run unidirectional causality running from GDP and CRW to international tourism, while there is long-run bidirectional causality between all considered variables. Long-run parameter estimates indicate that CRW consumption increases international tourism, while both CRW consumption and international tourism increase CO_2 emissions and GDP. These authors recommend that Tunisia should use more CRW energy, because this contributes to eliminate wastes from touristic zones, while it increases both the number of tourist arrivals and GDP. Our contribution in the present paper comes from studying the dynamic interaction between renewable energy and tourism and their long-run impact on CO_2 emissions using dynamic panel cointegration methods and a panel of Central and South American countries.

4 Data, empirical methodology, stationary, and cointegration

We obtain annual data, spanning the period 1995–2010 for a panel of 22 Central and South American countries.[1] The variables included in the empirical analysis are CO_2 emissions measured in kilo tons (kt), real gross domestic product (GDP, *Y*) measured in billion US $ constant 2005 prices, renewable energy consumption (RE) that involves all the available spectrum of renewable sources measured in billions of kilowatt hours (kwh), international tourism (TRS) defined as the total number of arrivals, the trade openness ratio (TR) measured as a share of GDP,[2] and foreign direct investment (FDI) inflows, measured as percentage of GDP. Data on CO_2 emissions, *Y*, TRS, TR, and FDI are obtained from the Word Bank (2014), while data on RE are obtained from the U.S. Energy Information Administration (2014). The Central and South American countries are selected to include the maximum number of observations depending on data availability.

Table 1 provides certain descriptive statistics of the selected country sample. These statistics are based on the tendency of the analysis variables across the selected time period. We deduce that Brazil has the highest level of real GDP during the selected period and reaches its maximum level (1100 billion US dollars) in 2010, while Dominica has reached the smallest level of real GDP (0.32 billion US dollars) in 1995. Brazil has also the highest levels of CO_2 emissions reaching its maximum level of 419,754.2 kt in 2010, whereas 73.34 kt is the lowest level of CO_2 emissions recorded in Dominica in 1996. The biggest renewable energy consumer is Brazil, reaching the highest level of 432.93 billion kwh in 2010, whereas Guyana is the smallest consumer of renewable energy having an approximately nil consumption during the period 2000–2010. The biggest total number of tourist arrivals is recorded in Brazil (5,358,000 in 2005), while the smallest number of total tourist arrivals is recorded in Suriname (43,000 in 1995). Guyana has realized the biggest trade openness ratios (163.65% in 1997) and Brazil has realized the smallest one (12.45% in 1996). St Vincent has realized the

[1] Selected countries: Argentina–Belize–Bolivia–Brazil–Chile–Costa Rica–Cuba–Dominica–Dominican Republic–Ecuador–El Salvador–Guatemala–Guyana–Honduras–Nicaragua–Panama–Paraguay–Peru–St Vincent–Suriname–Uruguay–Venezuela.

[2] The trade openness ratio is defined as the sum of exports and imports divided by the value of GDP.

Table 1 Descriptive statistics of the analysis variables

Variables	*Y*	CO_2	TRS	TR	RE	FDI
Mean	72.7	40,380.58	1,173,091	58.03	25.33	4.30
Maximum	1100	419,754.2	5,358,000	163.65	432.93	26.59
Minimum	0.32	73.34	43,000	12.45	0.00	− 16.59
Std. dev.	178	79,263.06	1,237,864	30.88	69.42	4.61
Skewness	4.02	2.76	1.57	1.22	4.13	0.84
Kurtosis	18.92	10.27	5	4.54	19.77	5.05
Jarque–Bera	4666.12	1223.80	204.54	121.65	5124.74	396.70
P values	0.00	0.00	0.00	0.00	0.00	0.00

Y gross domestic product (in constant 2005 billion US dollars), CO_2 carbon dioxide emissions (in kilo tons), *TRS* number of tourist arrivals, *TR* trade openness ratio (in %), *RE* renewable energy consumption (in billions of kilowatt-hours), *FDI* FDI inflows (as percentage of GDP)

biggest share of FDI (26.59% in 1997) and the lowest one has been realized by Suriname (− 16.59% in 2000).

Theoretically, we follow the same specification time series model developed by Katircioglu et al. (2014b) in which CO_2 emissions are affected by the tourism volume, economic growth, and energy consumption. In our paper, we have panel data, while we consider that international trade and FDI are also drivers for CO_2 emissions and use renewable energy consumption in place of energy consumption. Thus, the panel empirical model investigates the impact of economic growth, renewable energy consumption, international tourism, FDI, and international trade on CO_2 emissions:

$$\mathrm{CO}_{2it} = f(Y_{it}, \mathrm{RE}_{it}, \mathrm{TRS}_{it}, \mathrm{TR}_{it}, \mathrm{FDI}_{it}) \tag{1}$$

The natural logarithmic transformation of Eq. (1) yields the following equation:

$$\mathrm{CO}_{2it} = \alpha_i + \delta_i t + \beta_{1i} y_{it} + \beta_{2i} \mathrm{re}_{it} + \beta_{3i} \mathrm{trs}_{it} + \beta_{4i} \mathrm{tr}_{it} + \beta_{5i} \mathrm{fdi}_{it} + \varepsilon_{it}, \tag{2}$$

where $i = 1, \ldots, N$ for each country in the panel, $t = 1, \ldots, T$ denotes the time period, and ε_{it} denotes the stochastic error term. The parameter α_i allows for country-specific fixed effects.

To examine the dynamic causal relationship between variables, the empirical analysis will first test the integration order of each variable. Panel unit root tests of the first-generation may lead to spurious results (due to size distortions) if significant degrees of positive residual cross-section dependence exist and are disregarded. Therefore, the implementation of second-generation panel unit root tests is only desirable when it has been determined that the panel is subjected to a significant degree of residual cross-sectional dependence. In cases where cross-sectional dependence is not high enough, power loss may occur if second-generation panel unit root tests that allow for cross-sectional dependence are used. Consequently, before selecting the appropriate panel unit root test, it is important to provide some evidence of the degree of residual cross-sectional dependence.

The cross-sectional dependence statistic developed by Pesaran (2004) is based on a simple average of all pair-wise correlation coefficients of the ordinary least squares (OLS) residuals obtained from standard augmented Dickey–Fuller (ADF 1979) regressions for each variable in the panel. Under the null hypothesis of cross-sectional

Table 2 Cross-section dependence (CD) test: cross-section correlations of the residuals in ADF(*P*) regressions

Variables	Lags			
	1	2	3	4
co_2	[0.00][a]	[0.00][a]	[0.01][a]	[0.04][b]
re	[0.00][a]	[0.00][a]	[0.01][a]	[0.00][a]
y	[0.00][a]	[0.00][a]	[0.00][a]	[0.00][a]
trs	[0.00][a]	[0.00][a]	[0.02][b]	[0.03][b]
tr	[0.01][a]	[0.02][b]	[0.01][a]	[0.02][b]
fdi	[0.00][a]	[0.00][a]	[0.00][a]	[0.00][a]

Under the null hypothesis of cross-sectional independence, the CD statistic is distributed as a two-tailed standard normal. Results are based on the test of Pesaran (2004). Figures in brackets denote *P*-values. Significance levels: a (1%) and b (5%)

independence, a two-tailed standard normal distribution is asymptotically followed by the CD test statistic. The results presented in Table 2 reject the null hypothesis of cross-sectional independence. Thus giving evidence of cross-sectional dependence in the data due to the statistical significance of the CD statistics in any cases of the number of lags (from 1 to 4) comprised in the ADF regressions.

Two second-generation panel unit root tests are employed to determine the degree of integration in the respective variables. The Pesaran (2007) panel unit root test does not require the estimate of factor loading to eliminate cross-sectional dependence. Specifically, the usual ADF regression is augmented to comprise the lagged cross-sectional mean and its first difference to capture the CD that arises with a single-factor model. The null hypothesis is a unit root with the Pesaran (2007) test. The bootstrap panel unit root tests by Smith et al. (2004) use a sieve sampling scheme to take into account both the time series and CD in the data via bootstrap blocks. All four tests of Smith et al. (2004) are constructed with a unit root under the null hypothesis. Under the alternative hypothesis, they are constructed with heterogeneous autoregressive roots. The results of these panel unit root tests are given in Table 3 and support the presence of a unit root across all considered variables.

Given the unit root test results, we investigate the presence of cointegration within a heterogeneous panel context by using the Pedroni (2004) methodological approach. Pedroni (2004) proposes seven tests of cointegration which can be divided into two sets. The first set contains four panel statistics (v-statistic, rho-statistic, PP-statistic, and ADF-statistic) and assumes common autoregressive coefficients (within-dimension). The second set contains three group statistics (rho-statistic, PP-statistic, and ADF-statistic) and assumes individual autoregressive coefficients (between-dimension). All these tests are examined with intercept and deterministic trend. The null hypothesis is that there is no cointegration, while the alternative hypothesis is that there is cointegration between variables. Deviations from the long-run equilibrium relationship are represented by the estimated residuals ε_{it}. The null hypothesis of no cointegration ($\rho_i = 1$) is tested via the following unit root test on the residuals:

$$\varepsilon_{it} = \rho_i \varepsilon_{it-1} + \omega_{it} \quad (3)$$

The results from panel cointegration statistics are reported in Table 4. The number of lags is selected through the Schwarz information criterium (SIC), which sets it equal to

Table 3 Panel unit root tests

Variable	Pesaran CIPS	Pesaran CIPS*	Smith et al. *t* test	Smith et al. LM-test	Smith et al. max-test	Smith et al. min-test
co$_2$	− 1.25	− 1.31	− 1.42	3.02	− 1.25	1.35
Δco$_2$	− 5.52[a]	− 5.23[a]	− 5.32[a]	17.93[a]	− 6.62[a]	6.43[a]
re	− 1.28	− 1.26	− 1.25	3.15	− 1.29	1.28
Δre	− 5.59[a]	− 5.21[a]	− 6.24[a]	19.51[a]	− 7.75[a]	7.21[a]
y	1.14	− 1.22	− 1.28	2.36	− 1.33	1.25
Δ*y*	− 6.34[a]	− 6.48[a]	− 5.63[a]	18.74[a]	− 8.64[a]	6.46[a]
trs	− 1.52	− 1.42	− 1.24	1.23	− 1.29	1.18
Δtrs	− 7.84[a]	− 7.59[a]	− 6.11[a]	21.88[a]	− 7.94[a]	8.83[a]
tr	− 1.41	− 1.29	− 1.38	1.74	− 1.37	1.14
Δtr	− 7.39[a]	− 6.32[a]	− 5.53[a]	17.98[a]	− 7.71[a]	6.65[a]
fdi	− 1.36	− 1.31	− 1.27	1.26	− 1.28	1.22
Δfdi	− 6.97[a]	− 6.58[a]	− 6.24[a]	18.75[a]	− 6.86[a]	6.42[a]

Δ denotes first differences. A constant is included in the Pesaran (2007) tests. Rejection of the null hypothesis indicates stationary in at least one country. CIPS* = truncated CIPS test. Critical values for the Pesaran (2007) test are − 2.40 at 1%, − 2.22 at 5%, and −2.14 at 10%

"a" denotes rejection of the null hypothesis. Both a constant and a time trend are included in the Smith et al. (2004) tests. Rejection of the null hypothesis indicates stationary in at least one country. For both tests, the results are reported at lag = 4. The null hypothesis is that of a unit root

Table 4 Panel residual cointegration test results

	Statistic	Prob.	Weighted	
			Statistic	Prob.
Alternative hypothesis: common AR coefs. (within-dimension)				
Panel v-stat	− 4.873	0.00***	− 6.314	0.00***
Panel rho-stat	− 5.431	0.00***	− 7.809	0.00***
Panel PP-stat	− 9.623	0.00***	− 7.515	0.00***
Panel ADF-stat	− 6.815	0.00***	− 6.299	0.00***
Alternative hypothesis: individual AR coefs. (between-dimension)				
Group rho-stat	− 7.211	0.00***		
Group PP-stat	− 16.109	0.00***		
Group ADF-stat	− 7.898	0.00***		

Null hypothesis: no cointegration. "***" indicates statistical significance at the 1% level. We consider the case intercept and deterministic trend. Lag length selection is based on SIC with a max lag of 2. Newey–West automatic bandwidth selection and Bartlett Kernel

2. The panel cointegration results document that both panel statistics reject the null of no cointegration at the 1% significance level and confirm that there is a long-run relationship across the variables under study.

5 Long-run estimates

Once the long-run association between the variables under investigation is identified, we proceed to estimate the long-term structural coefficients of Eq. (2) using the fully modified OLS (FMOLS) and the dynamic OLS (DOLS) panel estimate methods, which are more efficient than the OLS method. In fact, the estimator computed through the OLS method is asymptotically biased and its distribution depends on nuisance parameters in the context of a panel estimate. Thus, to correct the estimator bias, Pedroni (2001, 2004)

Table 5 FMOLS and DOLS long-run estimates

Variable	FMOLS			DOLS		
	Coefficient	*t*-statistic	Prob.	Coefficient	*t*-statistic	Prob.
y	1.265	10.676	0.00***	1.216	11.516	0.00***
re	− 0.108	− 2.213	0.02**	− 0.103	− 2.348	0.03**
trs	− 0.354	− 3.297	0.00***	− 0.333	− 2.956	0.00***
tr	0.313	2.846	0.01***	0.283	2.216	0.04**
fdi	− 0.275	− 8.651	0.00***	− 0.269	− 3.986	0.00***

"***" and "**"indicate statistical significance at the levels 1% and 5%, respectively

propose to estimate systems of cointegrated variables by using the FMOLS technique. To correct the problems of endogeneity and serial correlation, the FMOLS method uses a non-parametric approach. The DOLS method is a parametric approach of panel estimate recommended by Kao and Chiang (2001) and by Mark and Sul (2003). The results are reported in Table 5 where the estimates include both an intercept and a trend factors.

The findings illustrate that all estimated coefficients are statistically significant. The FMOLS and DOLS estimates are very similar in terms of value, sign, and statistical significance. Overall, for the selected panel of countries, long-run results highlight that economic growth and trade are the major drivers for increasing CO_2 emissions. By contrast, renewable energy consumption, the number of tourist arrivals, and FDI inflows are major drivers for a significant decline in CO_2 emissions.

Indeed, for the case of FMOLS estimates, increasing GDP by 1% increases emissions by 1.26%. This is an expected result that can be explained by the fact that more economic growth necessitates more fossil energy for goods production leading to more CO_2 emissions. This result is similar to the majority of studies, such as in Lee and Brahmasrene (2013), Katircioglu (2014b), and de Vita et al. (2015). However, this finding is contrary to that of Ben Jebli et al. (2015a) who show that increasing GDP reduces CO_2 emissions in Tunisia. This last result can be attributed to the efforts made by Tunisia in abatement technologies, energy efficiency, and renewable energy use during the last three decades. The FMOLS estimates indicate that an increase of 1% in the trade openness ratio increases emissions of 0.31%. Such expected result can be explained by the fact that more trade openness may imply more imported and/or exported merchandises requiring more fossil energy to transport, to consume, or to produce them, implying increases in CO_2 emissions. This result is contrary to those found by Jayanthakumaran et al. (2012) on China and Dogan et al. (2017) on OECD countries.

Moreover, a 1% increase in renewable energy consumption reduces CO_2 emissions of 0.11% with the FMOLS method. This is an expected result that can be explained by the substitutability between fossil and renewable energy and by the reduction in the use of the former energy when renewable energy consumption is increased. This result is in accordance with those reached by Ben Jebli and Ben Youssef (2015a, exports model) and Ben Jebli et al. (2016). However, it is contrary to the findings by Apergis et al. (2010) on 19 developed and developing countries and by Ben Jebli et al. (2015a) study on Tunisia.

Interestingly, increasing the number of tourist arrivals by 1%, decreases CO_2 emissions by 0.35% with the FMOLS method. This result may be explained by the green tourism hypothesis, because an important proportion of tourists visiting Central and

Table 6 Panel residual cointegration test results (across income groups)

	Statistic	Prob.	Weighted	
			Statistic	Prob.
Lower-Middle-Income countries				
Alternative hypothesis: common AR coefs. (within-dimension)				
Panel v-stat	− 5.291	0.00***	− 6.715	0.00***
Panel rho-stat	− 6.392	0.00***	− 7.426	0.00***
Panel PP-stat	− 7.350	0.00***	− 7.148	0.00***
Panel ADF-stat	− 6.142	0.00***	− 6.168	0.00***
Alternative hypothesis: individual AR coefs. (between-dimension)				
Group rho-stat	− 6.945	0.00***		
Group PP-stat	− 12.547	0.00***		
Group ADF-stat	− 7.916	0.00***		
Upper-Middle-Income countries				
Alternative hypothesis: common AR coefs. (within-dimension)				
Panel v-stat	− 6.327	0.00***	− 7.709	0.00***
Panel rho-stat	− 6.918	0.00***	− 8.894	0.00***
Panel PP-stat	− 11.316	0.00***	− 8.645	0.00***
Panel ADF-stat	− 7.264	0.00***	− 7.632	0.00***
Alternative hypothesis: individual AR coefs. (between-dimension)				
Group rho-stat	− 7.942	0.00***		
Group PP-stat	− 13.906	0.00***		
Group ADF-stat	− 8.319	0.00***		
High-Income countries				
Alternative hypothesis: common AR coefs. (within-dimension)				
Panel v-stat	− 8.236	0.00***	− 8.732	0.00***
Panel rho-stat	− 9.147	0.00***	− 8.046	0.00***
Panel PP-stat	− 13.341	0.00***	− 7.749	0.00***
Panel ADF-stat	− 8.429	0.00***	− 7.657	0.00***
Alternative hypothesis: individual AR coefs. (between-dimension)				
Group rho-stat	− 9.836	0.000***		
Group PP-stat	− 15.554	0.000***		
Group ADF-stat	− 9.937	0.000***		

Null hypothesis: no cointegration. "***" indicates statistical significance at the 1 % level. We consider the case intercept and deterministic trends. Lag length selection is based on SIC with a max lag of 2. Newey–West automatic bandwidth selection and Bartlett Kernel

South America comes for the rich biodiversity of this region and for its cleanliness and wild beauty. Supported by the important revenues obtained from tourism, this pushed these countries to reduce their emission of pollution. This result is in accordance with those by Katircioglu (2014a) and Lee and Brahmasrene (2013). However, it is opposite to the findings by de Vita et al. (2015) and Katircioglu (2014b) on Turkey, Dogan et al. (2017) on OECD countries, and Ben Jebli et al. (2015a) on Tunisia.

Finally, a 1% increase in FDI leads to approximately 0.27% decrease in carbon emissions. This can be explained by the fact that several foreign direct investments are done in projects more efficient in energy or using renewable energy, or even in renewable energy production projects. These results are in accordance with a number of studies in the relevant literature. In particular, Zhu et al. (2016) use panel data from five countries, i.e., Malaysia, India, the Philippines, Thailand, and Singapore, spanning the period

1981–2011 to discover that the effect of FDI on carbon emissions is negative in countries with medium and high carbon emissions through panel quartile regressions, which supports the "pollution haloes hypothesis". In addition, Atici (2012) researches Asian countries and concludes that FDI is conducive to Asian countries reducing pollution. However, our result is in opposite direction to that of Salahuddin et al. (2018) showing that FDI increases CO_2 emissions in Kuwait.

This part of the empirical analysis considers specific clusters of the countries under examination through the criterion of GDP. In particular, based on the income classification from the World Bank, we consider the Lower Middle Income economies sample: Bolivia, El Salvador, Honduras and Nicaragua, the Upper-Middle-Income economies sample: Belize, Brazil, Cuba, Costa Rica, Dominica, Dominican Republic, Ecuador, Guatemala, Guyana, Paraguay, Peru, St. Vincent, Suriname and Venezuela, and the High-Income countries sample: Argentina, Chile, Panama and Uruguay. Table 6 reports the Pedroni cointegration test across the three samples. The new findings clearly indicate the presence of cointegration across all of them.

Next, Table 7 reports the country group estimates. The results document that the signs are retained according to their theoretical expectations, providing robustness to those obtained through the overall sample. However, for renewable energy, tourism, trade, and FDI variables, the strongest impact on carbon dioxide emissions comes in the case of the Lower Middle Income countries group. For the economic growth variable, the strongest impact on CO_2 emissions comes in the case of the High Income countries group.

6 Granger causality

We use Granger causality testing to examine the presence of any causal links across the variables under study. To achieve this, we run the pairwise Granger causality tests and the vector error correction model (VECM) for the short- and long-run relationships, respectively. Engle and Granger (1987) suggest two stages: the first stage recovers the estimated residuals from Eq. (2), while the second stage estimates the parameters related to the short-run adjustment. The estimate of the dynamic VECM is given as follows:

$$\begin{bmatrix} \Delta co_{2it} \\ \Delta y_{it} \\ \Delta re_{it} \\ \Delta trs_{it} \\ \Delta tr_{it} \\ \Delta fdi_{it} \end{bmatrix} = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \end{bmatrix} + \sum_{p-1}^{q} \begin{bmatrix} \varphi_{11p} & \varphi_{12p} & \varphi_{13p} & \varphi_{14p} & \varphi_{15p} & \varphi_{16p} \\ \varphi_{21p} & \varphi_{22p} & \varphi_{23p} & \varphi_{24p} & \varphi_{25p} & \varphi_{26p} \\ \varphi_{31p} & \varphi_{32p} & \varphi_{33p} & \varphi_{34p} & \varphi_{35p} & \varphi_{36p} \\ \varphi_{41p} & \varphi_{42p} & \varphi_{43p} & \varphi_{44p} & \varphi_{45p} & \varphi_{46p} \\ \varphi_{51p} & \varphi_{52p} & \varphi_{53p} & \varphi_{54p} & \varphi_{55p} & \varphi_{56p} \\ \varphi_{61p} & \varphi_{62p} & \varphi_{63p} & \varphi_{64p} & \varphi_{65p} & \varphi_{66p} \end{bmatrix} \times \begin{bmatrix} \Delta co_{2it-1} \\ \Delta y_{it-1} \\ \Delta re_{it-1} \\ \Delta trs_{it-1} \\ \Delta tr_{it-1} \\ \Delta fdi_{it-1} \end{bmatrix} + \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \\ \theta_5 \\ \theta_6 \end{bmatrix} \mathrm{ect}_{it-1} + \begin{bmatrix} \mu_{1it} \\ \mu_{2it} \\ \mu_{3it} \\ \mu_{4it} \\ \mu_{5it} \\ \mu_{6it} \end{bmatrix}, \tag{4}$$

where Δ is the first difference operator; the autoregression lag length, q, is determined by the Schwarz information criterion; ect is the error correction term derived from the long-run relationship of Eq. (2); μ is a random error term. Using the pairwise Granger

Table 7 FMOLS and DOLS long-run estimates (across income groups)

Variable	FMOLS		DOLS	
	Coefficient	Prob.	Coefficient	Prob.
Lower-Middle-Income economies				
y	0.784	0.00***	0.706	0.00***
re	− 0.177	0.01***	− 0.159	0.01***
trs	− 0.416	0.00***	− 0.393	0.00***
tr	0.379	0.00***	0.351	0.00***
fdi	− 0.326	0.00***	− 0.305	0.01***
Upper-Middle-Income economies				
y	0.995	0.00***	0.953	0.00***
re	− 0.136	0.01***	− 0.121	0.01***
trs	− 0.378	0.00***	− 0.352	0.00***
tr	0.346	0.00***	0.329	0.00***
fdi	− 0.294	0.01***	− 0.279	0.02**
High-Income economies				
y	1.437	0.00***	1.324	0.00***
re	− 0.107	0.01***	− 0.085	0.02**
trs	− 0.326	0.01***	− 0.309	0.01***
tr	0.303	0.01***	0.286	0.02**
fdi	− 0.238	0.02**	− 0.213	0.02**

"***" and "**" indicate statistical significance at the levels 1% and 5%, respectively

Table 8 Short- and long-run causality tests

Dependent variable	Short run						Long run
	Δco_2	Δ*y*	Δre	Δtrs	Δtr	Δfdi	ECT
Δco_2	–	2.197 [0.18]	6.536*** [0.01]	0.0078 [0.86]	0.385 [0.63]	0.0026 [0.94]	− 0.038** [0.03]
Δ*y*	5.783** [0.04]	–	1.516 [0.19]	0.176 [0.57]	0.139 [0.62]	0.674*** [0.00]	0.086 [0.24]
Δre	0.086 [0.76]	3.454** [0.05]	–	0.178 [0.61]	0.094 [0.69]	0.017 [0.96]	− 0.079** [0.03]
Δtrs	1.208 [0.22]	8.226*** [0.00]	2.106 [0.18]	–	2.549 [0.16]	0.075 [0.73]	− 0.215*** [0.00]
Δtr	1.925 [0.18]	5.327** [0.04]	4.547** [0.05]	4.773** [0.05]	–	1.229*** [0.00]	− 0.0852*** [0.00]
Δfdi	8.763*** [0.00]	10.438*** [0.00]	0.785 [0.19]	9.439*** [0.00]	6.409*** [0.00]	–	− 0.128*** [0.00]

"***", "**" indicate statistical significance at the 1% and 5% levels, respectively. *P* values are listed in brackets

causality tests, we obtain the short-run interactions across the variables. The estimated coefficients of the error correction term indicate the adjustment of the dependent variable to its long-run equilibrium. We use both t-statistic and F-statistic tests for the significance of the long- and short-run dynamic relationships, respectively. The results of these short- and long-run causalities are reported in Table 8.

Table 8 shows the presence of short-run unidirectional causality running from output to trade. This signifies that economic growth stimulates exports and/or imports of merchandise even in the short-run. There is also short-run unidirectional causality running from output to the number of tourist arrivals, which implies that economic growth generates better services and is a good signal for attracting tourists. These results are in accordance with those reported by Katircioglu (2009b). There is also short-run unidirectional causality running from renewable energy consumption to the trade openness ratio. Indeed, because of the substitutability between renewable and fossil energy, increasing the former may reduce the imports of fossil energy in these countries. In addition, more renewable energy consumption impacts on the quantity of produced and traded goods. This result is similar to that by Ben Jebli and Ben Youssef (2015b), while is in the opposite direction to that by Ben Youssef and Ben Jebli (2015a) showing, for the case of Tunisia, the presence of short-run unidirectional causality running from trade (exports or imports) to renewable energy. We also document short-run unidirectional causality running from renewable energy consumption to CO_2 emissions that may be due to the substitutability between renewable and fossil energy. This finding is in accordance with that by Ben Jebli et al. (2015a), but differs from that by Apergis et al. (2010) who show the presence of bidirectional causality between renewable energy and emissions in the short-run for the case of a panel of 19 developed and developing countries.

Short-run causality running from the number of tourist arrivals to the trade openness ratio without feedback occurs. Indeed, the tourism sector contributes to the exports efforts of these countries through the foreign currency given by tourists, while it contributes to imports of merchandise, because these tourists use goods and services among which some are imported. This result is opposite to that by Katircioglu (2009b) who shows the presence of unidirectional causality running from trade to tourism for the case of Cyprus. In addition, the findings point out the significance of short-run causality running from carbon emissions to FDI. It seems that pollution emission attracts foreign investors to this region for the realization of projects more efficient in energy or using renewable energy. Our last result differs from that of Salahuddin et al. (2018) study on Kuwait showing the presence of a short-run unidirectional causality running from FDI to CO_2 emissions.

Table 8 also reports that the error correction term (ECT) is statistically significant in relevance to the equations of CO_2 emissions, renewable energy consumption, the number of tourist arrivals, trade, and FDI. However, the ECT is not statistically significant for the economic growth equation. Therefore, there are long-run bidirectional causalities between the five variables renewable energy, tourism, FDI, trade, and emissions. The presence of long-run bidirectional causality between renewable energy consumption and the number of tourist arrivals is an interesting result similar to that established by Ben Jebli et al. (2015a) for the case of Tunisia. It implies that increasing renewable energy use attracts more tourists, because the latter are more concerned with environmental protection. In addition, more international tourists give more foreign currency to these countries, thus, enabling them to invest in renewable energy projects. Thus, a policy designed for the development of the tourism sector could be a good supportive policy for the expansion of the share of renewable energy in the total energy mix.

7 Conclusions and policy implications

This paper examined the dynamic causal linkages between CO_2 emissions, economic growth, renewable energy consumption, the number of tourist arrivals, foreign direct investment, and the trade openness ratio for a panel of 22 Central and South American countries, spanning the period 1995–2010. This empirical analysis also explored the long-run impact of five considered variables on CO_2 emissions. A particular attention was given to the causal relationships between tourism and renewable energy. Using panel cointegrations, the empirical findings documented that the long-run relationship between the considered variables is strongly supported when CO_2 emissions turned to be the dependent variable.

Based on the FMOLS and DOLS estimates, long-run results documented that economic growth and trade significantly contributed to more CO_2 emissions. Indeed, any increase in real GDP or in the share of merchandise trade exchanges increased the level of pollution in the region under study. However, and interestingly, renewable energy consumption, the number of tourist arrivals, and FDI were substantial drivers for the decline of CO_2 emissions. The first result is due to the substitutability between fossil and renewable energy, implying that an increase in renewable energy consumption reduces fossil energy consumption and the associated pollution emissions. We can explain the second result by the green tourism hypothesis. Indeed, an important proportion of tourists visiting Central and South America come for its rich biodiversity, cleanliness, and wild beauty. The important revenues obtained from tourism incited these countries to reduce their pollution emissions. Our last result can be explained by the involvement of several foreign direct investments in energy saving and renewable energy. The signs of our long-run elasticity estimates have been confirmed when considering specific clusters of the countries under examination through the income classification from the World Bank.

Short-run Granger causality tests highlighted unidirectional causality running from renewable energy consumption to CO_2 emissions, indicating the pivotal role of renewable energy in the reduction of such emissions. Moreover, there was amble evidence for the presence of unidirectional causality running from economic growth, renewable energy consumption, and the number of tourist arrivals to trade. Also, there are short-run bidirectional causalities between FDI and GDP, and between FDI and trade openness. In the long run, the vector error correction model displayed the presence of bidirectional causalities between all the relevant variables, except for that of economic growth. The presence of long-run bidirectional causality between renewable energy consumption and the number of tourist arrivals was a worth considering result. It can be explained by the fact that increasing renewable energy use attracts more tourists, because they are more sensitive to environmental protection, while more international tourists can bring more foreign currency for investing in renewable energy projects.

The empirical findings raise a number of substantial policy implications for this region related to: (i) encouraging the adoption of clean technologies using renewable energy for production purposes seems to be a major driver for significantly enhance environmental quality levels; (ii) policies that support the development of the tourism sector seem to be a good vehicle to combat global warming in this region. Emphasizing the development of green tourism is of great interest for this region on both the economic and environmental sides. As recommended by the United Nations Environment Program (2011), public–private partnerships can spread the costs and risks of large green tourism investments. In addition, administrative fees related to these projects can be reduced by public authorities by offering favorable interest rates and in-kind support, such as technical, marketing, or business administration assistance; (iii) the long-run dynamic bidirectional causal relationship between the number of tourist arrivals and renewable energy consumption indicates that a policy designed to the development of the tourism sector could be a good supportive strategy for the expansion of the share of renewable energy in the total energy mix. On the other side, encouraging the use of renewable energy enhances the venue of tourists to this region; (iv) FDI benefits this group of countries, both economically and environmentally. They are advised to attract more FDI by making further efforts to improve their infrastructure, qualify their workforce, improve administrative procedures, etc. Finally, one extension of our work could be the study of the relationship between tourism and renewable energy by including other variables, while considering other countries or a panel of countries.

Authors' contributions
All authors have substantially contributed to this research paper. All authors read and approved the final manuscript.

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Competing interests
The authors declare that they have no competing interests. This article is original, has not already been published in a journal, and is not currently under consideration by another journal.

Ethics approval and consent to participate
We agree to the terms of the Springer Open Copyright and License Agreement.

Funding
No funding has been received to realize this research.

Informed consent
All authors of the manuscript have read and agreed to its content and are accountable for all aspects of the accuracy and integrity of the manuscript in accordance with ICMJE criteria.

Publisher's Note

Received: 11 January 2018 Accepted: 16 January 2019
Published online: 19 February 2019

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