Current Issues in Tourism

ISSN: 1368-3500 (Print) 1747-7603 (Online) Journal homepage: https://www.tandfonline.com/loi/rcit20

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To cite this article: Eyup Dogan, Fahri Seker & Serap Bulbul (2017) Investigating the impacts of energy consumption, real GDP, tourism and trade on CO_2 emissions by accounting for cross-sectional dependence: A panel study of OECD countries, Current Issues in Tourism, 20:16, 1701-1719, DOI: 10.1080/13683500.2015.1119103

To link to this article: https://doi.org/10.1080/13683500.2015.1119103

Published online: 11 Dec 2015.

Current Issues in Tourism, 2017
Vol. 20, No. 16, 1701–1719, http://dx.doi.org/10.1080/13683500.2015.1119103

Routledge Taylor & Francis Group

Investigating the impacts of energy consumption, real GDP, tourism and trade on CO_2 emissions by accounting for cross-sectional dependence: A panel study of OECD countries

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(*Received 28 September 2015; accepted 8 November 2015*)

The objective of this study is to analyse the long-run dynamic relationship of carbon dioxide emissions, real gross domestic product (GDP), the square of real GDP, energy consumption, trade and tourism under an Environmental Kuznets Curve (EKC) model for the Organization for Economic Co-operation and Development (OECD) member countries. Since we find the presence of cross-sectional dependence within the panel time-series data, we apply second-generation unit root tests, cointegration test and causality test which can deal with cross-sectional dependence problems. The cross-sectionally augmented Dickey-Fuller (CADF) and the cross-sectionally augmented Im-Pesaran-Shin (CIPS) unit root tests indicate that the analysed variables become stationary at their first differences. The Lagrange multiplier bootstrap panel cointegration test shows the existence of a long-run relationship between the analysed variables. The dynamic ordinary least squares (DOLS) estimation technique indicates that energy consumption and tourism contribute to the levels of gas emissions, while increases in trade lead to environmental improvements. In addition, the EKC hypothesis cannot be supported as the sign of coefficients on GDP and GDP^2 is negative and positive, respectively. Moreover, the Dumitrescu–Hurlin causality tests exploit a variety of causal relationship between the analysed variables. The OECD countries are suggested to invest in improving energy efficiency, regulate necessary environmental protection policies for tourism sector in specific and promote trading activities through several types of encouragement act.

Keywords: energy consumption; tourism; environmental impacts; cross-sectional dependence; policy implementation

1. Introduction

Tourism is a rapidly developing sector that grows each year with more arrival points emerging around the world. According to the United Nations World Tourism Organization (UNWTO) 2015 Report, the overall number of tourists travelled around the world increased from 25 million in 1950 to a half billion in 1995, and more than one billion in 2014.[1] The UNWTO also anticipates that the average annual growth rate of international tourist travels will be around 3.5% by 2030. The dramatic increase in the number of international tourist arrivals within several decades attracts attentions of many groups including researchers, economists and policy-makers. Its contribution to the economy is one key feature of tourism. For example, the large number of touristic travels resulted in revenue of

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approximately $1200 billion in addition to indirect revenue of around $200 billion through tourism-led exports in 2014. The revenue of the tourism sector through direct, indirect and induced impact is around 10% of the gross domestic product (GDP) of the world in the same year. In addition to the tourism sector, growth of the value of international trade is also worth mentioning. In other words, the real value of merchandise trade increased from $8 trillion in 1980 to $16 trillion in 2000 and $28 trillion in 2014 according to the World Development Indicators (WDI).[2] The total money value of merchandise trade was equal to approximately 48% of the real world output in 2014. Similar to the development in international tourism and trade, energy consumption and carbon dioxide (CO_2) emissions have shown increasing trends globally for the last several decades. By referring to the up-to-date data by the WDI, total world energy consumption increased from approximately 6 billion tons of oil equivalent (btoe) in 1980 to 10 btoe in 2000, and 13 btoe in 2010; in addition, world total CO_2 went up from about 19 billion metric tons (bmt) in 1980 to 25 bmt in 2000, and 34 bmt in 2010. In short, tourism, trade, real output, energy consumption and gas emissions together have followed an increasing trend for many years.

The relationship between tourism and real GDP or economic growth is well established and investigated for single country cases and multi-country cases in the literature (Arslanturk, Balcilar, & Ozdemir 2011; Aslan, 2015; Balaguer & Cantavella-Jorda, 2002; Balcilar, Van Eyden, Inglesi-Lotz, & Gupta 2014; Bilen, Yilanci, & Eryüzlü 2015; Dritsakis, 2004; Kim & Chen, 2006; Oh, 2005; Pérez-Rodríguez, Ledesma-Rodríguez, & Santana-Gallego, 2015; Santana-Gallego, Ledesma-Rodríguez, Pérez-Rodríguez, & Cortés-Jiménez, 2010). The energy consumption–economic growth nexus is also analysed for a variety of cases (Aslan, Apergis, & Yildirim 2014; Bloch, Rafiq, & Salim 2015; Dogan, 2015; Ozturk, 2010; Yildirim, Saraç, & Aslan, 2012). In addition to these nexus, Tang and Abosedra (2014) investigate the relationship among energy consumption, economic growth and tourism in a multivariate framework for Middle East and North Africa (MENA) countries, and find that energy consumption and tourism contribute to the real output. Furthermore, tourism has become a recent variable of interest explored in the environmental economics literature as a potential factor affecting the levels of CO_2 emissions (De Vita, Katircioglu, Altinay, Fethi, & Mercan, 2015; Katircioğlu, 2014a, 2014b; Katircioglu, Feridun, & Kilinc, 2014; Lee & Brahmasrene, 2013). Most of the state of the art focuses on the existence of the Environmental Kuznets Curve (EKC) hypothesis which postulates an inverted U-shaped relation between CO_2 emissions and GDP levels stating that CO_2 emissions start to decrease at higher levels of GDP after some threshold. Empirical findings are mixed depending on several factors, one of which is the level of economic development and industrialization of the country under investigation. For example, tourism contributes to gas emissions through creating an economy of transportation, building of touristic facilities, and local and government services in some countries (De Vita et al., 2015; Gossling, 2013; Katircioglu et al., 2014). On the other hand, the opposite type of relation is held for some countries in which tourism is negatively associated with CO_2 emissions through supportive policies and government interventions for low gas emission levels, and creating a movement towards the use of cleaner technologies (Lee & Brahmasrene, 2013).

A resulting increase in trade volume is one of the widely established aspects of tourism as a positive externality. According to the UNWTO 2015 Report, tourism accounts for 6% of the total global exports and 30% of the global exports of services in 2014. The share of tourism in total world trade volume is the fourth largest item after fuels, chemicals and food exports. The mechanism that relates tourism to trade may work through fair trade tourism as well as through the creation of extra foreign exchange stock in the country which in turn supports international trade. The positive relation of tourism to trade is so far found to be economically sound by more than a few studies (Khan, Toh &, Chua 2005; Santana-Gallego, Ledesma-Rodríguez, & Pérez-Rodríguez, 2011; Shan & Wilson, 2001). Within the same scope, the relationship among trade and CO_2 emissions is another recently investigated nexus in the literature (Halicioglu, 2009; Jayanthakumaran, Verma, & Liu 2012; Sbia, Shahbaz, & Hamdi 2014). Evidence in line of the literature regarding effects of trade on CO_2 emissions is mixed as the effect might depend on three factors, namely, scale, technique and composition as discussed by Farhani, Chaibi, and Rault (2014). The scale effect basically implies that the increases in the amount of trade influence output, energy consumption and thus CO_2 emissions. The composition effect refers to the reallocation in a country's traded goods basket. Hence, the use of energy and environmental quality may increase or decrease depending on whether or not the sectors that the country keeps going to produce need more energy. The technique effect means that trade liberalization leads to environmental improvements since the technology gets better in producing goods and using energy more efficiently. Given the mixed evidence for the effect of trade and tourism on CO_2 emissions, it becomes interesting to search whether these variables have an important role in explaining CO_2 emissions as well as the EKC hypothesis.

In regard to country selection, the Organization for Economic Co-operation and Development (OECD) is a group that includes a set of countries typically characterized by a large number of tourist arrivals, and a large volume of international trade, industrial production, gas emissions and energy consumption. According to the WDI, the OECD member countries generated a real GDP of $39 trillion and consumed 5,5 btoe of energy, which accounted for about 75% of the real world GDP and 42% of the world total energy consumption in 2010. Regarding the tourism sector, the OECD Tourism Trends and Policies 2014 states that tourism accounted for 4–5% of GDP, 6% of the total employment and 21% of the exports of services in the OECD countries.[3] In addition to that, the number of tourist arrivals in OECD countries constituted 57% of the total tourism arrivals and accounted for 59% of the total tourism receipts worldwide. Moreover, the levels of CO_2 emissions that the OECD countries exposed were 13 bmt and accounted for about 40% of the global gas emissions level in 2010 referring to the WDI. Lastly, the focus on the OECD countries is economically sound and beneficial to be investigated as they are in general responsible for the major part of worldwide energy consumption, output, gas emissions, and tourism and trade activities.

This study makes several contributions to the existing literature. As empirical contributions, for the first time in the literature this study analyses the energy–environment–growth nexus and the EKC hypothesis by simultaneously including trade and tourism in a multivariate framework, even though the relationship between two or three of them is separately investigated in various literatures such as energy–growth literature, tourism–growth literature and energy–growth–environment literature. In addition, this study focuses on the panel study of OECD countries because the selected group has an important role in energy, trade and tourism sectors, and produces a significant share of the world GDP and gas emissions. Because refusing to recognize the problem of cross-sectional dependence can result in unreliable results and cause econometrically dangerous consequences, as methodological contributions, this study uses second-generation unit root tests (the CADF and CIPS panel unit root tests), the cointegration test (the Lagrange multiplier (LM) bootstrap panel cointegration test) which accounts for cross-sectional dependence problem since Pesaran's CD test (Pesaran, 2004) shows that disturbances in each panel time-series data are cross-sectionally dependent. Then, the dynamic ordinary least squares (DOLS) technique considered as a second-generation estimator is employed to reveal the coefficient estimates. In addition, a second-generation causality test; namely, the Dumitrescu–Hurlin causality test rather than a conventional Granger causality test is employed because Dumitrescu and Hurlin (2012) assume all coefficients to vary across cross sections as different from a standard causality approach. Moreover, it works well enough in the case of cross-sectional dependence. The next section provides a body of existing literature. Section 3 elaborates the data and model used in the present study. Section 4 explains the methods and reveals the findings. The last section is the conclusion.

2. Literature review

A vast number of studies have so far analysed the energy–environment–growth nexus for various cases. Most studies investigate this nexus by using a simple EKC framework in which gas emissions are regressed on energy consumption (EGY), GDP (or economic growth) and real GDP^2 only. Recent studies include some relevant variables such as trade (TR) and tourism (TOUR) into the simple EKC model so as to control for omitted-variable bias problem and measure the effects of these variables on the environment. Henceforth, we divide the literature review section into three subsections to give a clearer brief of a survey for the mentioned nexus.

2.1. *Energy consumption, CO_2 emissions and economic growth*

The literature on the link between CO_2 emissions, economic growth and energy consumption has widely expanded so far with studies regarding various countries, regions and groups. For example, Ang (2007) examines the case of France with data covering years 1960–2000. The author finds causality running from output growth to EGY and CO_2 emissions in the long run. One-way causality from EGY to output growth is found in the short run. Soytas, Sari, and Ewing (2007) investigate the case of the USA with data covering years 1960–2004. Results suggest long-run causality from EGY to CO_2 emissions and no long-run causality from income to pollution. By focusing on Malaysia for the period 1971–1999, Ang (2008) finds causality running from GDP to EGY in both the long run and the short run. In addition, they find that causality runs from EGY to GDP, from GDP to EGY and from CO_2 emissions to economic growth in the long run. Soytas and Sari (2009) examine the case of Turkey with data covering years 1960–2000 and identify unidirectional causality from carbon emissions to energy consumption, whereas, in another study, Ozturk and Acaravci (2010) examine cases of Albania, Bulgaria, Hungary and Romania for the period 1968–2005 and find significant causality only for the case of Hungary. The causality is bidirectional between EGY and GDP. Similarly, Pao and Tsai (2011) examine multiple countries: Brazil, Russian Federation, India and China with data for the years 1992–2007. The authors find two-way causal relationship between EGY and GDP, and between GDP and pollution. In another study examining multiple countries, Chandran and Tang (2013) examine cases of Malaysia, Indonesia, Singapore, the Philippines and Thailand for the years 1971–2008. The authors do not find a significant relationship among the variables except for Malaysia, Thailand and Indonesia. For Indonesia and Thailand, the causality turns out to be bidirectional among GDP and environmental degradation, while for Malaysia it is unidirectional from GDP to CO_2 levels. The causality between transport EGY and CO_2 levels is also found to be bidirectional for Thailand, Malaysia and Indonesia. Park and Hong (2013) examine the case of South Korea by using data for the period 1991–2011. Results suggest that economic growth and CO_2 emissions are moving in the same direction, and fossil fuel consumption precedes economic growth. Omri (2013), on the other hand, examines the case of MENA region for the period 1990–2011, and exploits two-way causality between energy consumption and economic growth and one-way causality running from energy consumption to CO_2 emissions. Kivyiro and Arminen (2014) examine the same type of relation for the case of sub-Saharan African Countries: Congo, DRC, Kenya, South Africa, Zambia and Zimbabwe. The authors use data covering years 1971–2009 and analyse the possible presence of a long-run link between GDP, EGY and foreign direct investment (FDI). They find unidirectional causality running from energy consumption to GDP and from FDI to GDP for the case of Congo; unidirectional causality from FDI to CO_2 emissions and from GDP to CO_2 emissions for the case of Congo; unidirectional causality from FDI to CO_2 emissions, from GDP to CO_2 emissions and from GDP to FDI for the case of Kenya; unidirectional causality from EGY to pollution, from FDI to CO_2 emissions and from GDP to FDI for the case of South Africa; no significant causality for the case of Zambia and lastly, unidirectional causality from GDP to FDI in Zimbabwe. Saboori, Sapri, and bin Baba (2014) examine the long-run relation between energy consumption of road transport, GDP and CO_2 emissions for the OECD in a panel study for the period 1960–2008. The authors identify bidirectional causality between pairs of all three variables for each of the 27 OECD countries. Alshehry and Belloumi (2015) examine the dynamic relationship between energy consumption, GDP and CO_2 emissions for the case of Saudi Arabia. Their findings indicate the existence of long-run causality among energy consumption, energy price, CO_2 emissions and economic growth. In the short run, authors identify unidirectional causality running from CO_2 to energy consumption and GDP.

2.2. *CO_2 emissions, energy consumption, economic growth and trade*

Suri and Chapman (1998) is one of the earlier works that examine the existence of EKC hypothesis with a focus on trade through trade's increasing effect on energy consumption. The authors use a data set that involves 33 countries for the time period 1971–1990 or 1991 depending on data availability and use the fixed effects generalized least squares (GLS) regression for the panel data. Findings show that increase in the trade volume moves the turning point of the EKC curve to the right, meaning that international trade increases environmental pollution levels, possibly through a mechanism of higher demand for commercial energy use. Therefore, the authors suggest a positive relationship between trade and CO_2 emissions for the countries that are in the industrialization process and hence are at the increasing part of the EKC. For the case of Turkey, Halicioglu (2009) examines the relation between CO_2 emissions, energy consumption, GDP and foreign trade. The author uses data for the period 1960–2005 and applies an autoregressive distributed lag (ARDL) bounds test to search for cointegration among the variables. The findings suggest positively significant relation between environmental degradation and EGY, CO_2 emissions and GDP, and CO_2 emissions and TR in the long run. The directions of short-run coefficients turn out to be positive and the magnitude of coefficients is similar as well. Jalil and Mahmud (2009) also examine the link between CO_2 emissions, EGY, GDP and TR in the long run by focusing on the case of China with data from 1975 to 2005. They also test the validity of the EKC hypothesis. The ARDL approach followed by Granger causality tests is employed and results suggest a statistically significant relationship between all the variables in the model. According to the results, GDP and GDP^2 Granger cause CO_2 emissions. The coefficient on energy consumption turns out to be positive and significant, and the coefficient on foreign trade turns out to be insignificant. Jayanthakumaran et al. (2012) examine the relationship between GDP, TR, EGY and environmental degradation for cases of China and India by using the ARDL method with data for years 1971–2007. The authors support the validity of the EKC hypothesis and also find that increases in EGY contribute to pollution for both countries. For China, findings suggest a positive causality from EGY to CO_2 emissions in both the long run and the short run. The relationship between TR and CO_2 is not significant in the long run and it is significant yet small in magnitude in the short run. For India, increases in GDP increase CO_2 emissions, and trade openness has no significant impact on CO_2 emissions in the long run. Farhani et al. (2014) investigate the relationship between CO_2 emissions, GDP, EGY and TR for Tunisia. The authors apply the ARDL bounds testing approach and the Granger causality tests with a panel vector error correction model (VECM) to the data from 1971 to 2008. In the long run, EGY, economic growth and TR are all found to positively affect CO_2 emissions. The EKC hypothesis is supported in the long run. Moreover, EGY and TR are found to cause CO_2 emissions. In addition, unidirectional causality is found from GDP, GDP^2 and EGY to CO_2 emissions in the short run. In another study, Sbia et al. (2014) examine the dynamics of FDI, EGY, economic growth and CO_2 emissions for United Arab Emirates by applying the ARDL bounds testing approach with a dynamic unrestricted error correction model (UECM) and Granger causality tests to data from 1975 to 2011. Results show that FDI, CO_2 emissions and TR have negative impacts on energy demand, while economic growth boosts EGY. According to Granger causality test results, there is bidirectional causality between FDI and EGY, and between FDI and economic growth in the long run. Furthermore, TR Granger causes FDI, EGY and pollution. In the short run, findings support bidirectional causality between FDI and EGY and between economic growth and EGY, whereas unidirectional causality is found from TR to gas emissions. Omri , Daly, Rault, and Chaibi (2015) focus on the link among CO_2 emissions, TR, economic growth and financial development for MENA countries. The authors conduct estimation with simultaneous generalized method of moments for the panel data including 12 MENA countries for years 1990–2011. The coefficient of financial development on economic growth is positive and significant for 6 of 12 countries (Algeria, Egypt, Iran, Jordan, Morocco and Tunisia); similarly, the coefficient of nuclear energy consumption on economic growth is positive and significant. The coefficient of trade openness on GDP per capita turns out to be positive and significant for 9 out of 12 countries, whereas for Egypt and Oman it turns to have a significant negative impact. Regarding the explanatory variables of CO_2, the authors find that per capita GDP has a positive and statistically significant effect for 9 out of 12 countries. TR also has a positive and significant effect on CO_2 emissions but for three countries: Algeria, Bahrain and Qatar only. The coefficient on EGY is positive and statistically significant for all the countries.

2.3. *Energy consumption, CO_2 emissions, economic growth and tourism*

In order to analyse the long-run dynamics of tourism receipts per capita, economic growth, FDI and CO_2 emissions, Lee and Brahmasrene (2013) investigate a panel data of European Union countries covering the years 1988–2009. The authors use Fisher-type Johansen panel cointegration test and panel-based error correction methods to determine the long-run equilibrium relationship among the variables. They support the existence of a long-run relationship between all the four variables. According to the findings, TOUR directly and positively affects economic growth; economic growth positively affects CO_2 emissions, while tourism mitigates pollution. Similarly, Katircioğlu (2014a) investigates the relationship between CO_2 emissions, GDP, EGY and tourist arrivals to determine the existence and direction of causality from GDP, energy consumption and tourist arrivals to CO_2 emissions for the case of Singapore. The author uses a log model and employs bounds tests, conditional

Granger causality tests and the DOLS method to determine the existence of a long-term relationship between TOUR and CO_2 emissions through channels of EGY and economic growth. Findings support the existence of EKC hypothesis in both the short run and the long run with a positive coefficient on GDP and a negative one on GDP^2. The coefficient on tourism turns out to be statistically significant and negative, suggesting a decreasing effect of tourism on CO_2 emission levels. The coefficient on energy consumption turns out to be statistically significant and positive. The model is overall significant and supports one-way causality running from energy consumption, GDP and tourist arrivals to CO_2 emissions in the long run. The link between CO_2 emissions, energy consumption and tourist arrivals for the case of Cyprus, which is an island that receives more than 2 million tourists each year, is investigated by Katircioglu et al. (2014). The authors use data covering the years 1970–2009 and employ error correction mechanisms, bounds tests in the ARDL approach and the Granger causality tests for both long run and short run. Results suggest a positive effect of tourism on CO_2 emissions and energy consumption, with the effect on energy consumption being larger in magnitude. The coefficient on tourism indicates a relation to CO_2 in the long run, whereas the short-run coefficient is insignificant. Granger causality test yields unidirectional long-run causality from tourism and energy consumption to CO_2 emissions, meaning that an increase in tourist arrivals will precede increases in energy consumption and CO_2 emissions. Katircioğlu (2014b), similarly, examines the long-run relationship between CO_2 emissions, EGY and TOUR for Turkey. The author uses the ARDL approach to cointegration and an error correction mechanism with data from 1960 to 2010. In the long run, the author finds a positive and significant relation between TOUR and pollution, between EGY and CO_2 emissions and between GDP and CO_2 emissions. The short-term coefficients on gas emissions of TOUR, GDP and EGY are all positive and statistically significant. Solarin (2014) investigates the effect of tourism development and energy consumption together with financial development and urbanization on CO_2 emissions for Malaysia. The author uses the ARDL approach, the Granger causality test and the DOLS methods. Results suggest the presence of cointegration among them when CO_2 emission level is taken as the response variable. The coefficients of both TOUR and GDP turn out to be positive and significant in the long run and short run, whereas the coefficient on financial development is negative and significant in both the long run and short run. In the model involving all the variables, the coefficient of energy consumption turns out to be insignificant, suggesting a possibility for tourism to account for the effect of energy consumption through increasing energy use. León, Arana, and Hernández Alemán (2014) examine the contribution of TOUR to environmental degradation separately for the case of developed and less developed countries. The authors apply the generalized method of moments (GMM) method together with the fixed effects GLS estimation by using a panel data set for 14 developed and 31 less developed countries. The model includes CO_2 emissions as the dependent variable, and tourist arrivals, the population, GDP, energy efficiency and the share of industrial output in total output as the explanatory variables. Results suggest that the effect of TOUR is positive for both developed and less developed countries. The positive effect of tourism turns out to be three times smaller in less developed countries. De Vita et al. (2015) investigate the case for Turkey of the existence of the EKC hypothesis by controlling for tourist arrivals. The authors employ cointegration tests and the DOLS estimation method to determine the effect of GDP, GDP^2, energy consumption and tourism on CO_2 emissions in a log model by using data for the years 1960– 2009. The long-run coefficients on GDP and GDP^2 turn out to be significant and they support the EKC hypothesis. The coefficient on EGY is significant and positive, and the coefficient on tourism is also significant and positive.

3. Model specification and data

The studies of Ang (2007), Soytas et al. (2007), Wang, Zhou, Zhou, and Wang (2011), Chandran and Tang (2013), Omri (2013) and Yavuz (2014), among others, investigate the environment–output–energy nexus under the EKC framework in which gas emissions are regressed on GDP, the square of GDP and energy consumption. For a panel study, it can be written as:

$$(CO_2)_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDP_{it}{}^2 + \beta_3 EGY_{it} + e_{it}. \tag{1}$$

In addition to energy consumption and real output, Farhani et al. (2014), Shahbaz, Khraief, Uddin, and Ozturk (2014), Tiwari, Shahbaz, and Hye (2013), Jayanthakumaran et al. (2012), Nasir and Rehman (2011), Jalil and Mahmud (2009) and Halicioglu (2009) emphasize the importance of trade openness in determining the levels of CO_2. By including trade openness as an additional variable into the simple EKC framework, it can be shown as in Equation (2):

$$(CO_2)_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDP_{it}{}^2 + \beta_3 EGY_{it} + \beta_4 TR_{it} + e_{it}. \tag{2}$$

Recently, Lee and Brahmasrene (2013), Katircioğlu (2014a) and De Vita et al. (2015) show that tourism is a statistically significant element for the environment and thus should be added as a separate factor into the simple EKC model as indicated in Equation (3):

$$(CO_2)_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDP_{it}{}^2 + \beta_3 EGY_{it} + \beta_4 TOUR_{it} + e_{it}. \tag{3}$$

As a contribution to the existing literature, we combine Equations (2) and (3) so as to simultaneously estimate the impacts of tourism and trade openness on CO_2 emissions under a modified EKC framework. The new approach takes the following form as in Equation (4):

$$(CO_2)_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDP_{it}{}^2 + \beta_3 EGY_{it} + \beta_4 TR_{it} + \beta_5 TOUR_{it} + e_{it}, \tag{4}$$

where i and t stand for cross sections and the time; e denotes normally distributed error term and $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ are the coefficient estimates of the relevant variables. CO_2 is carbon dioxide gas emissions in metric tons as a proxy for environmental pollution; GDP is the value of real gross domestic product in constant 2005 US$; EGY is energy consumption in kilogram of oil equivalent; TOUR is the number of international tourist arriving and staying in OECD countries; TR is trade openness measured as the ratio of merchandise trade to the value of GDP. The annual panel time-series data are from 1995 to 2010 are taken from the World Bank's "World Development Indicators" (http://data.worldbank.org). This study uses the logarithmic values of the data. It is worth knowing that this study employs the longest available data with the information that the data for tourism are not available before 1995, and the data for gas emissions are not available after 2010. We admit that it would absolutely be better to work with a relatively longer data; nevertheless, we believe that this study contributes to the state of the art as to understand the importance of TOUR and TR in addition to GDP, GDP^2 and EGY in the EKC-type model and the importance of cross-sectional dependence even though the analysis is constrained by the data availability. The OECD countries used in this study are Turkey, the UK, Sweden, Greece, Belgium, Japan, Netherlands, the USA, France, Iceland, Portugal, Denmark, Germany, Switzerland, Korea Rep., Israel, Italy, Slovenia, Australia, Ireland, Canada, Norway, Austria, Poland, Chile, Spain and Mexico.

4. Methods and empirical results

4.1. *Panel unit root analysis*

This study first looks at whether cross-sectional dependence exists within the panel time-series data by applying Pesaran's CD test (Pesaran, 2004) in advance to examining integration properties of CO_2, GDP (GDP^2), energy consumption, trade and tourism. The correlation between the time series for each OECD member may take place due to either globally known events with heterogeneous effects on members or local spillover effects among members. In the presence of cross-sectional dependence in the panel time-series data, the CADF and the CIPS panel unit root tests due to Pesaran (2007) should be preferred over widely used first-generation conventional panel unit root tests because the conventional panel unit root tests suppose no dependency across the series, and thus do not consider the existence of possible cross-sectional dependence. This supposition can cause misleading results.

The results of the CD test for each variable are reported in Table 1. We have strong evidence to reject the null hypothesis of cross-sectional independence for all of the analysed variables. In other words, CO_2, GDP (GDP^2), energy consumption, tourism and trade have cross-sectional dependence. Therefore, this study applies the CADF and the CIPS panel unit root tests to each of the individual panel time-series data. The application process of both the tests is identical, except that the CIPS test uses the cross-sectional average of the CADF test. Building on the Augmented Dickey–Fuller (ADF) approach, these panel unit root tests take the following form:

$$\Delta x_{i,t} = \alpha_i + \beta_i x_{i,t-1} + \rho_i T + \sum_{j=1}^{n} \theta_{ij} \Delta x_{i,t-j} + \varepsilon_{i,t}, \tag{5}$$

where x_{it} stands for an analysed variable, ε_{it} is the error term, Δ is the difference operator and α and T are individual intercepts and time trends, respectively. The appropriate lag lengths are selected based on the Akaike Information Criterion. Both tests perform the null hypothesis that all individuals within a panel data are not stationary versus the alternative hypothesis that at least one individual is stationary process:

$$H_0{:}\beta_i = 0,$$

$$H_a{:}\begin{cases} \beta_i < 0 & \text{for } i = 1, 2, \ldots, N_1 \\ \beta_i = 0 & \text{for } i = N_1 + 1, N_1 + 2, \ldots, N \end{cases}$$

Table 1. Results from cross-sectional dependence test for panel time-series data.

	CO_2	GDP (GDP^2)	EGY	TOUR	TR
CD test	13.63***	72.30***	30.27***	44.29***	41.03***
p value	0.00	0.00	0.00	0.00	0.00

Note: The CD test performs the null hypothesis of cross-sectional independence.***The statistical significance at the 99% level.

Table 2 reports the results of Pesaran's CADF and CIPS panel unit root tests. We find that CO_2, GDP (GDP^2), energy consumption, tourism and trade are not stationary at their levels; however, they are stationary process at their first differences since we have enough evidence to reject the null hypothesis of unit root at 99% level of significance. The panel time series should either be stationary at their levels or have an established long-run relationship in order to have economically meaningful and reliable estimates of explanatory variables. As these time-series data contain unit root at their levels, this study performs a panel cointegration test to see whether or not the analysed variables have a long-run relationship.

4.2. *Panel cointegration test*

In order to exploit the possible presence of cointegration among CO_2, GDP, GDP^2, EGY, TOUR and TR, we apply a second-generation panel cointegration, namely, the LM bootstrap panel cointegration test due to Westerlund and Edgerton (2007) that considers cross-sectional dependence. This test is based on LM test of McCoskey and Kao (1998) and uses bootstrap technique relying on sieve scheme. Some advantages of the LM bootstrap panel cointegration test are that it works well in the existence of cross-sectional dependence; it has good small sample properties; it reduces asymptotic test distorting using the bootstrap method; it performs the null hypothesis of cointegration. Given that the employed data have a cross-sectional dependence and are relatively small, this test is expected to produce a reliable output for the cointegration relation among the analysed variables. The LM bootstrap cointegration test is employed by a number of studies from different literatures, for example, Erdem, Nazlioglu, and Erdem (2010), Mahdavi and Westerlund (2011), Arouri, Youssef, M'henni, and Rault (2012), Afonso and Rault (2015) and Chortareas, Magkonis, Moschos, and Panagiotidis (2015).

As shown in Table 3, the results obtained from the LM bootstrap panel cointegration test indicate that the null hypothesis of cointegration between gas emissions, real output, GDP^2, energy consumption, trade and tourism against the alternative hypothesis of no cointegration relationship among the analysed variables cannot be rejected at 90% level of significance because the relevant p values are far greater than significance levels. Furthermore, such a long-run relationship of the independent and dependent variables is found by using both constant only and constant-trend models. In short, there is a cointegration relationship between the response variable (CO_2 emissions) and explanatory variables (energy consumption, GDP, GDP^2, tourism and trade), referring to p values, and they

Table 2. Results from panel unit root test.

	CADF		CIPS	
	Level	Δ	Level	Δ
CO_2	−1.36	−2.80***	−2.04	−4.35***
GDP (GDP^2)	−1.69	−2.50***	−1.34	−2.50***
EGY	−1.38	−2.35***	−1.85	−3.92***
TOUR	−1.98	−2.46***	−1.85	−3.19***
TR	−1.63	−3.15***	−1.65	−3.15***

Note: Δ is the first difference term. Critical values are not reported for the sake of brevity but can be provided upon request.***The statistical significance at the 99% level.

Table 3. Results from the LM bootstrap panel cointegration test.

	Constant		Constant and trend	
Tests	Test statistic	Bootstrap p value	Test statistic	Bootstrap p value
LM bootstrap	82.040	.177	125.588	.352

Note: The bootstrap test is based on Westerlund and Edgerton (2007) and run using 2000 replications. This test performs the null hypothesis of cointegration in the panel for all units against the alternative hypothesis of no cointegration in the panel (at least for a cross-sectional unit).

move together over the long run. Henceforth, the long-run estimators are supposed to provide economically meaningful and reliable estimates of independent variables.

4.3. *The long-run estimates*

Lee (2007) notes that the panel fully modified ordinary least squares (FMOLS) and the panel DOLS, among others, are implemented as alternative measuring methods accompanying the knowledge that the ordinary least squares (OLS) procedure produces invalid standard errors due to second-order asymptotic bias. Moreover, Kao and Chiang (2000) employ Monte Carlo experiments to identify small sample characteristics of the FMOLS and the DOLS estimations, and indicated that the panel DOLS performs better in small samples than the panel FMOLS and OLS. In addition, Narayan and Smyth (2007) claim that the DOLS produces consistent coefficient estimates of explanatory variables in small samples as it accounts for possible endogeneity and serial correlation problems. Furthermore, the DOLS generates unbiased coefficient estimates as noted by Pedroni (2001). A few of recent studies in the energy–environment literature (Katircioğlu, 2014a; Lean & Smyth, 2010; Osabuohien, Efobi, & Gitau 2014; Solarin, 2014) that use small sample size also adopt the DOLS as an estimation method. Because the size of our sample group is relatively small, this study uses the DOLS technique in order to reveal the long-run coefficient estimates of GDP, GDP^2, EGY, TOUR and TR. By following Kao and Chiang (2000), and Pedroni (2001), the regression of the DOLS estimator is given in Equation (6):

$$Y_{it} = \alpha_i + \beta_i X_{it} + \sum_{i=-p_i}^{p_i} c_{ip} \Delta X_{it-p} + \mu_{it}, \tag{6}$$

where Y_{it} is CO_2 and X represents the vector of GDP, GDP2, EGY, TOUR and TR in the present study. In addition, α_i, β_i, $-p_i$ and p_i, and μ_{it} represent individual effect, coefficient of slope, lead and lag of difference, and error term, respectively.

Table 4 shows the findings obtained from the DOLS test in Equation (6). Since we use the logarithm values of the panel time-series data, the long-run coefficient estimates of GDP, GDP^2, energy consumption, tourism and trade are econometrically equal to the elasticities of CO_2 with respect to output, the square of output, EGY, TOUR and TR, respectively, It is worth mentioning that the reported coefficient estimates are all statistically significant at either 95% level of significance or 99% level of significance referring to the given p values and t-statistics. Starting with economic growth, the results show that the sign of coefficients on GDP and the square of GDP are negative and positive, respectively, indicating a U-type relationship between income and gas emissions. Given the

Table 4. Results from the panel DOLS.

Dependent variable: CO_2			
Independent variables	Coefficient	*t*-statistic	*p* value
GDP	−4.65***	−6.65	.00
GDP^2	0.19***	6.56	.00
EGY	0.93***	16.7	.00
TOUR	0.03**	2.18	.03
TR	−0.13***	−4.61	.00
R^2	0.99		
Coefficient diagnostic (null hypothesis: $\beta_4 = 0$, $\beta_5 = 0$)			
Test statistic	Value	df	*p* value
F-statistic	11.13	(2, 378)	.00
Chi-square	22.27	2	.00

Note: Coefficient diagnostic test evaluates the joint hypothesis where the null is that the coefficients of TOUR and TR are equal to zero.**The statistical significance at the 95% level.***The statistical significance at the 99% level.

(partial) marginal effect of GDP on CO_2 is obtained by $\beta_1 + 2*\beta_2*GDP$ ($-4.65 + 2*0.19*GDP$) for this study, the (partial) marginal effect of GDP is clearly negative for low levels of income; but it increases and eventually becomes positive as the OECD members reach higher levels of income. This implies that there is no evidence of the presence of an inverted U-shaped relationship, or equivalently, no evidence of the EKC hypothesis for the examined OECD member countries. In other words, the increases in the amount of real output cause environmental degradation after passing the threshold level. The finding of no EKC hypothesis in the present study is consistent with that of Ozturk and Acaravci (2010), Wang et al. (2011), Du, Wei, and Cai (2012), Chandran and Tang (2013), Al-mulali, Saboori, and Ozturk (2015), Farhani and Ozturk (2015) and Dogan and Turkekul (2015).

Considering the effect of energy consumption on pollution, the increases in EGY have nearly one-to-one impact on the levels of gas emissions. More precisely, a 1% rise in energy consumption increases CO_2 emissions by 0.93%. As anticipated, the use of energy upgrades environmental degradation. This result is consistent with that of almost all studies in the literature, including Ang (2007), Ozturk and Acaravci (2010), Omri (2013), Shahbaz et al. (2014), Kanjilal and Ghosh (2013), Dogan and Turkekul (2015) and Kasman and Duman (2015). Trade openness is the last variable of interest to be interpreted in the present study. Table 4 shows that the elasticity of gas emissions with respect to trade is −0.13. In other words, a 1% increase in trade causes 0.13% decreases in CO_2 emissions in the long run. This implies that the OECD member countries are mostly specialized in the production of environmentally friendly goods, and take advantages of technique effect of trade to lower gas emissions. It is also worth mentioning that these two effects polish off the scale effect of trade in the OECD countries. This result is consistent with that of Suri and Chapman (1998), Halicioglu (2009), Dogan and Turkekul (2015) and Al-mulali et al. (2015).

Tourism has positive and significant effects on CO_2 emissions. In other words, a 1% increase in tourist arrivals causes 0.03% increases in the levels of gas emissions. Although the coefficient on tourism is relatively smaller, it is still significantly different from zero. Thus, tourism sector is found to contribute to gas emissions in the OECD countries through several channels such as transportation, building of touristic facilities, and local and government services. In addition, supportive policies and government interventions for low gas emissions levels, and creating a movement towards the use of cleaner technologies related to tourism activities may be in place but not enough to reduce CO_2 emissions. This finding is in line with that of Katircioğlu (2014b), Katircioglu et al. (2014), Solarin (2014) and De Vita et al. (2015).

In conjunction with reporting the coefficient estimates, it is noteworthy that Table 4 also includes a coefficient diagnostic test that evaluates the joint hypothesis where coefficients of tourism and trade are equal to zero. Therefore, we can compare the results obtained through this study to those found by previous studies, which include CO_2 emissions, GDP, the square of GDP and energy consumption in a base EKC model. In other words, the diagnostic test investigates whether or not restricting tourism and trade reduces the goodness of fit of the model. Both the *F*-statistic and the Chi-square exhibit that we have enough evidence to reject the null hypothesis that the coefficient estimates of tourism and trade are equal to zero ($\beta_4 = 0$ and $\beta_5 = 0$) in favour of the alternative hypothesis that $\beta_4 \neq 0$ and $\beta_5 \neq 0$. Thus, the inclusion of tourism and trade into the base model increases the fit of the model. Although the results for the base (nested) model are not reported for the sake of brevity, the coefficient estimates of GDP, GDP^2 and EGY are −4.89, 0.20 and 0.98, and statistically significant at 99% level of significance. The coefficient estimates from the nested model are greater than those from the modified EKC model wherein tourism and trade are included as additional explanatory variables.

4.4. *Dumitrescu–Hurlin panel Granger causality test*

Once the long-run relationship among the analysed variables is established, and the long-run estimates are reported, it is of interest for researchers to make use of a Granger causality test to expose the causal relationship between gas emissions, economic growth, EGY, TOUR and TR. The knowledge of the causal direction helps policy-makers to impose relevant policies for sustainable environment and economic growth. To this end, we use Dumitrescu–Hurlin causality test due to Dumitrescu and Hurlin (2012). As different from a standard Granger causality approach, this test assumes all coefficients to vary across cross sections. In addition, the authors by using Monte Carlo experiments show that this test fits well enough to a relatively short span of data even in the existence of cross-sectional dependence. In addition, this causality approach can be applied in the case of both T > N and T < N and for unbalanced and heterogeneous panels. Dumitrescu and Hurlin (2012) consider the following linear heterogeneous model:

$$y_{i,t} = \alpha_i + \sum_{i=1}^{K} \gamma_i^{(k)} y_{i,t-k} + \sum_{i=1}^{K} \beta_i^{(k)} x_{i,t-k} + \varepsilon_{i,t}, \tag{7}$$

with $K \in N^+$ and $K \in \mathrm{N}^*$ and $\beta_i = (\beta_i^{(1)}, \ldots\ldots, \beta_i^{(K)})$ and α_i, $\gamma_i^{(k)}$ and $\beta_i^{(k)}$ indicate constant term, lag parameter and coefficient slope, respectively. The null and alternative hypotheses are defined as:

$$H_0{:}\beta_i = 0,\ H_1{:}\begin{cases} \beta_i = 0 \quad \forall_i = 1, 2, \ldots\ldots\ldots N \\ \beta_i \neq 0 \quad \forall_i = N_1 + 1,\ N_1 + 2,\ \ldots\ldots, N \end{cases}$$

More specifically, the null hypothesis supports the existence of no homogenous Granger causality for all cross-sectional units, whereas the alternative hypothesis assumes that there is at least one causal relationship in the panel data. The results from the Dumitrescu–Hurlin causality test are given in Table 5. We have strong evidence to support bidirectional causality between economic growth and pollution, between EGY and gas emissions, GDP and EGY, GDP and TR. In addition, one-directional causal relationship is detected from TOUR to CO_2 emissions, from TR to gas emissions, from GDP to tourism, from TOUR to energy consumption, from TR to EGY and from TOUR to trade. All of the findings are statistically significant as shown in Table 5. These results are in line with the findings of several studies such as Ang (2007), Soytas et al. (2007), Ang (2008), Chiou-Wei, Chen, and Zhu 2008 (2008), Soytas and Sari (2009), Pao and Tsai (2011), Chandran and Tang (2013), Saboori et al. (2014), Farhani et al. (2014), Dogan (2015), Liddle and Lung (2015) and Dogan and Turkekul (2015).

The findings on causal relationship among the response and explanatory variables are consistent with those found in the long-run estimation section. In detail, the levels of GDP (the square of GDP) are found to have an impact on the levels of gas emissions; in addition, energy consumption is a significant determinant of environmental degradation. Because of the existence of feedback effects between GDP and EGY, it is not quite possible to reduce the levels of gas emissions through decreasing the amount of energy consumption without harming economic growth. Thus, the relevant institutions in the OECD should carry out enough numbers of investment projects to upgrade energy efficiency for the sake of environmental quality. Furthermore, tourism sector is one of the main contributors to gas emissions and trade openness as expected and discussed in the Section 1. Since this study finds in the preceding section that the increase in trade openness leads to environmental improvements, and shows that tourism sector Granger causes trade, tourism sector through trade indirectly reduces CO_2 emissions; however, it has a negative direct

Table 5. Results from Dumitrescu–Hurlin panel causality tests.

Hypothesis	*W*-statistic	*p* value	Result	Conclusion
$GDP(GDP^2) \rightarrow CO_2$	4.56***	.00	Yes	Bidirectional causality between GDP and CO_2
$CO_2 \rightarrow GDP(GDP^2)$	2.64***	.00	Yes	
$EGY \rightarrow CO_2$	2.95***	.00	Yes	Bidirectional causality between EGY and CO_2
$CO_2 \rightarrow EGY$	2.64***	.00	Yes	
$TOUR \rightarrow CO_2$	2.71***	.00	Yes	Unidirectional causality from TOUR to CO_2
$CO_2 \rightarrow TOUR$	1.49	.58	No	
$TR \rightarrow CO_2$	3.54***	.00	Yes	Unidirectional causality from TR to CO_2
$CO_2 \rightarrow TR$	1.01	.63	No	
$EGY \rightarrow GDP(GDP^2)$	2.19***	.00	Yes	Bidirectional causality between GDP and EGY
$GDP(GDP^2) \rightarrow EGY$	4.61***	.00	Yes	
$TOUR \rightarrow GDP (GDP^2)$	1.73	.16	No	Unidirectional causality from GDP to TOUR
$GDP (GDP^2) \rightarrow TOUR$	2.77***	.00	Yes	
$TR \rightarrow GDP(GDP^2)$	2.86***	.00	Yes	Bidirectional causality between GDP and TR
$GDP(GDP^2) \rightarrow TR$	3.29***	.00	Yes	
EGY→TOUR	1.23	.92	No	Unidirectional causality from TOUR to EGY
TOUR→EGY	2.49***	.01	Yes	
EGY→TR	1.63	.25	No	Unidirectional causality from TR to EGY
TR→EGY	2.71***	.00	Yes	
TOUR→TR	1.90*	.07	Yes	Unidirectional causality from TOUR to TR
TR→TOUR	1.44	.52	No	

*Statistical significance at the 90% level.***The statistical significance at the 99% level.

effect on environmental quality due to increases in the use of transportation, buildings, energy and services for the tourism activities. As the growth-led tourism hypothesis is detected for the OECD members, the reduction in tourism arrivals has no effect on GDP. This growth-led tourism hypothesis is consistent with several articles (Pablo-Romero & Molina, 2013). Overall, policy-makers should impose policies in regard to environmental protection, and encourage the use of cleaner technologies in the tourism sector. Lastly, the OECD should encourage firms to accelerate the volume of foreign trade because of its adverse effect on the levels of emissions.

5. Conclusions

This study analyses and exploits the long-run dynamics of CO_2 emissions, GDP, GDP^2, energy consumption, tourism and trade for the OECD member countries over the period of 1995–2010. As apart from a large part of previous literature, we test the possible presence of cross-sectional dependence in the panel time-series data, and accordingly, choose to employ second-generation unit root tests, namely, the CIPS and CADF panel unit root tests; a second-generation cointegration test, namely, the LM bootstrap panel cointegration test; and a second-generation causality test, namely, the Dumitrescu–Hurlin causality test, all which are fine choices in the existence of cross-sectional dependence. In addition, this study estimates the long-run coefficients of energy consumption, GDP, the square of GDP, tourism and trade by using the DOLS technique, which is also a second-generation estimator and superior to the OLS and the FMOLS techniques for relatively small samples.

The CD test reports that CO_2 emissions, GDP, GDP^2, energy consumption, tourism and trade have cross-sectional dependence at 99% level of significance. The CIPS and CADF panel unit root tests show that all of the analysed variables contain a unit root at their levels, but become stationary at their first differences at 99% level of significance. The LM bootstrap panel cointegration test indicates that the analysed variables are cointegrated; alternatively, gas emissions, output, the square of output, energy consumption, trade, and tourism have a long-run relationship. Thus, the coefficient estimates are assumed to be economically reliable and meaningful. According to the DOLS method, energy consumption and tourism cause environmental degradation, while trade leads to environmental improvements. In addition, the validity of the EKC hypothesis is not found for the OECD members because the effects of GDP and GDP^2 on the levels of emissions are negative and positive, respectively, and thus a U-shaped relationship is found. Referring to the results from the Dumitrescu–Hurlin causality test, there is bidirectional causality between CO_2 and GDP, CO_2 and energy consumption, and GDP and energy consumption. In addition, this study exposes one-way causality running from tourism to trade, from tourism to CO_2 emissions, from economic growth to tourism, from tourism to energy consumption, from trade to energy consumption, and from trade to gas emissions.

In regard to policy implications, the overall results imply that the reduction in the use of energy unlikely lowers the levels of CO_2 emissions without harming economic growth because of the presence of bilateral impacts among economic growth and energy consumption. Therefore, the OECD countries alternatively target to improve energy efficiency through proper policies and investment projects, so that environmental quality increases as less energy is needed to produce the same amount of products and services in case of higher energy efficiency. Furthermore, the positive effect of tourism on CO_2 emissions for the OECD countries provides evidence on the hypothesis that tourism development leads to increased levels of CO_2 emission through increasing the use of energy and transport to promote touristic facilities. Thus, policy-makers should impose policies in regard to environmental protection, and encourage the use of cleaner technologies in the tourism sector since the tourism sector increases gas emissions in the OECD countries. Lastly, it is advised that policy-makers should also regulate such policies to trigger trade activities as trade openness detracts CO_2 emissions.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. Available at www.unwto.org
2. Available at data.worldbank.org
3. Available at www.oecd.org

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