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RESEARCH ARTICLE

Pollutant emission effect of tourism, real income, energy utilization, and urbanization in OECD countries: a panel quantile approach

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Abstract
Although the Organization for Economic Co-operation and Development (OECD) member countries are largely regarded as a high human development index and high-income economies, evidence has continued to reveal the existential gap among the member countries drive toward achieving environmental sustainability. Giving this motivation, this research employed a panel quantile approach to examine the role of square of per capita income (the environmental Kuznets curve–EKC hypothesis) and per capita income, tourist arrivals, energy consumption, and urbanization on environmental quality in the panel of (31) selected OECD countries over the period 1995–2016. A handful of vital results were presented in the study. First, the evidence of EKC (inverted *U*-shaped) proposition is establish just for the lower quantiles while a no EKC (*U*-shaped) hypothesis is found from the 0.25th to 0.90th quantile. In specific, environmental quality starts to improve when the per capita real income peaked at 11, 271.13 USD (0.05th quantile) and 8, 604.15 USD (0.10th quantile) while the environment becomes damaged after income per capita becomes 89, 321.72 USD (0.25th quantile) and 36, 315.50 USD (0.50th quantile). Moreover, the effect of international tourism arrivals, urbanization, and energy consumption are all significant and damaging to environmental quality across the quantile but with a slightly minimized impact toward the upper quantile. Furthermore, there is statistical significant evidence of Granger causality at least from tourism development, energy consumption, urbanization, and per capita income to carbon emissions. Considering the aforementioned results, the study outlined relevant policy mechanism that is poised to guide the OECD member countries on the sustainable development path.

Keywords Environmental sustainability · Tourism · Real income · EKC · OECD

Introduction

> During the next decade, we have a short window of time to significantly increase steps to conserve biodiversity, reduce the effects of climate change, and drastically reduce our natural resource use. We have the expertise, technology, and resources required to make important systems of production and consumption such as food, transportation, and renewable energy. Our economic

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stability and well-being are dependent on this and on our ability to empower societal change to enact change and make it a better place.
- Hans Bruyninckx, the Executive Director of the European Environment Agency (EEA) (2020)

According to the State of Environment Report (SOER 2020), the European climate and environment policies in the last decades have facilitated the improvement of the environment; however, the region is not making adequate progress and the projections for the coming decade about the environment is not promising. The SOER (2020) report gave a summary of past trend and projections for meeting the region's policies and objectives. This objective include natural resources conservation theme that has been endangered through urbanization and land of the last 10 to 15 years and even to 2030 and 2050 projections. In the low-carbon and resource-efficient economy theme, greenhouse gas emissions, renewable energy sources, and emissions of air pollutant, the relatively encouraging trend in 2020 is likely to be overturned by 2030 and 2050. Thus, it is clear that urbanization, emissions, and energy play a pivotal role in environmental sustainability in European and other Organization for Co-operation and Development (OECD) member countries.

Based on Álvaro et al.' (2016) report, 75% of the European population lives in the urban cities in 2015, and anticipates that by 2050, the figure could rise to 80%. The study posits that urbanization has a positive relationship with income, labor productivity, competitiveness level, and technology adoption. It further maintained that urbanization positively correlates with ICT developments, quality of workforce, and infrastructure in Europe. However, the study of the nexus of urbanization and environmental sustainability within different context presents divided opinions (Al-Mulali et al. 2015; Farhani and Ozturk 2015; Majeed and Ozturk 2020). Also, on the nexus of urbanization and energy intensity, Belloumi and Alshehry (2016) noted that a decrease in energy intensity is likely possible in the countries that are associated with higher gross domestic product (GDP); thus, environmental sustainability vis-a-vis is attainment is such circumstance. Within this framework, extant studies have illustrated the interrelationship between energy consumption, urbanization, and environmental sustainability across different countries, and especially the OECD member countries (e.g., Jebli et al. 2016; Özokcu and Özdemir 2017; Zaman et al. 2016; Tiwari et al. 2013; Iwata et al. 2011; Solarin and Shahbaz 2013).

Furthermore, the relationship between environmental sustainability, energy consumption, and tourism has been widely researched (Akadiri et al. 2020; Alola et al. 2019a; Katircioglu 2014; Saint Akadiri et al. 2019a). With the increase in energy consumption in the tourism industry arising from travels and tourism activities, there are increasing concerns (Sharpley and Telfer 2015) that the industry is contributing significantly to climate change via its impact on carbon emission. Ninety percent of energy consumption occurs during arrivals and departure to the destination of which, 15% is railways and sea, 42% by land, and 43% by air (Karabuga et al. 2015). Out of the total global CO_2 emissions, tourism emits 5% (Işik et al. 2017). According to World Tourism Organization and International Transport Forum (2019), Europe will continue to be the largest CO_2 emitter through international tourism (an estimation of about 225 million tonnes in 2030 from 175 million tonnes in2016), because the region is the largest destination and origin of international tourism travel. Increase in tourist arrivals contributes to the destination country's economy (Lasisi et al. 2020; Uzuner et al. 2020) as well as increases energy consumption (Katircioglu 2014). However, the effects of tourism development, urbanization, energy consumption, CO_2 emissions, and sustainable income are to be explored in this study.

There are a number of reasons to substantiate our study of the OECD countries. Firstly, the current study advanced and close the gap in the existing literature of Galeotti et al. (2006), Iwata et al. (2011), Jebli et al. (2016), Özokcu and Özdemir (2017), and Zaman et al. (2016) on OECD such that the environmental sustainability of the OECD countries is examined from the perspective of quantile regression. In further closing, the gap in the literature, the environmental Kuznets curve (EKC) hypothesis is investigated such that the turning points (indicating the maximum per capita income) at each quantile is examined. In addition, the impacts of energy consumption, international tourism arrivals, and urbanization are examined for the first time across the quantile representations of the panel of OECD countries. In general, by employing the aforementioned approaches especially in the framework of panel second-generation approach that considers the cross-sectional dependency, this study is considered novel and possesses the potential of bridging the existing gap in the literature.

The remaining section consists of the literature review, information about the dataset, methodology, discussion, and conclusion respectively.

Literature review

According to the United Nations Population Fund (UNPF 2016), more than half of the population in the world is currently residing in metropolises and towns, and the figure is expected to increase to about 5 billion by 2030. Because of increased urbanization among other factors, studies have revealed that urbanization, energy consumption, tourism activities, economic growth, and related activities contribute to pollutant emissions.

Pollutant emissions determinants

According to Shahbaz et al. (2016), urbanization can result in different types of snags like resource depletion, ecological damage, traffic congestion, water, and air pollution which threaten sustainability at local, national, and global level. On the other hand, Tupy (2015) and Zhou et al. (2012) believe that urbanization have a positive impact because it might reduce the degradation of the environment owing to efficient resource consumption which will, in turn, enhance environmental quality.

From Table 1 above, the effect of urbanization on environmental sustainability is dependent on several factors such as rate and stage of urbanization, population, the country in context, among others.

Pollutant emissions from tourism and related economic activities

The study of Earlier, Bertinelli and Black (2004) opined that economic growth is influenced through the channels of (a) health, employment, and education capital; (b) agglomeration of enterprises and people which reduces the production and transaction costs; (c) promotion of business ideas, easier access to finance, and urbanite market with higher consumer density to carry out transactions; (d) through migration, active interaction between rural and urban areas, and transmittals. For instance, Katircioglu (2014) opined that energy consumption, carbon emission, and international tourism to Turkey are cointegrated. The study further revealed that both energy consumption and international tourism worsen environmental quality in Turkey. Similarly, Zaman et al. (2016) examined the impact of tourism development and energy consumption on carbon emission in 34 developed and developing countries in the framework of EKC hypothesis. While the EKC hypothesis was validated by the study, it further affirmed a tourism-induced carbon emissions causal relationship. In addition, Eluwole et al. (2020) found a non-significant relationship between tourism and environmental sustainability in 10 pollutant emission countries while other related studies posited a significant relationship between tourism and pollutant emissions (Saint Akadiri et al. 2019b; Lasisi et al. 2020; Uzuner et al. 2020)

Data description and methodology

Data description

In the determining role of energy consumption, urbanization, tourism, and the real income, especially the growth of the real income in the environmental quality of the panel of the OECD countries, a selection of 31 OECD member countries[1] for the period 1995–2016 is considered. The values of the implied variables or proxies are transformed to a natural logarithm. Indicatively, further information regarding the measurement and sources of the dataset is provided in the upper part of Table 2. Furthermore, the descriptive statistics of the dataset are illustrated in the lower part of Table 2, while an additional statistical inference provides correlation evidence of among the variables as depicted in Table 3. In specific, the descriptive statistics revealed that there is a higher deviation in the values of energy consumptions and carbon emissions while the statistical evidence of normal distribution is rejected for all the series except real income per capita at a 1% significant level. Importantly, considering the tendency of having country-specific factors across the selected 31 OECD countries, the cross-sectional dependency test is considered essential (De Hoyos and Sarafidis 2006). In essence, the cross-sectional dependency (CD) tests of Pesaran (2004), Breusch and Pagan (1980) were employed with the results (reject the null hypothesis of cross-sectional dependence) that indicated in the lower part of Table 3.

Empirical method

Considering that the determinants of environmental quality in the OECD are examined within the framework of tourism development, urbanization, energy consumption, real income, and the growth of real income, then the carbon function model is deemed appropriate for the current study. Earlier studies such as Dietz and Rosa (1994), Stern (2004), and Stern et al. (1996) have put forward the influence of affluence (wealth), population, and energy consumption on the environmental/ecological system. Following these aforementioned studies, recent studies have equally considered a handful of expanded factors such as income, urbanization, tourism activities, human development index, migration, and among several others within the framework of the ecological system (Adedoyin et al. 2020a; Adedoyin et al. 2020b; Alola and Alola 2018; Alola et al. 2019b, c; Al-Mulali and Ozturk 2015; Shahbaz et al. 2012). Moving forward, the linear functional form in the current context is presented as:

$$\mathrm{LECM} = f\ (\mathrm{LGDP}, \mathrm{LTOU}, \mathrm{LENU}, \mathrm{LURB}) \quad (1)$$

Quantile regression

Following the evidence of series stationarity after first difference (see Table 4) after employing the Cross-sectionally Im, Pesaran and Shin (CIPS) of Pesaran (2004) and Im et al. (2003) panel unit root tests, we proceed to investigate the implied CEM and explanatory variables relationship. The current study has derived the advantages of the quantile regression (QR) approach because of its appropriateness to

[1] Belgium, Czech Republic, Denmark, Finland, Germany, Greece, Hungary, Italy, Japan, Korea Republic (South Korea), Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Sweden, the UK, Bulgaria, Croatia, Cyprus, Romania, Australia, Austria, Israel, Mexico, New Zealand, and the USA

Table 1 A review of urbanization and the environment

Reference	Year	Country	Variables	Outcomes
Buşu and Buşu (2017)	2007	Romania	CO_2 emissions, GDP, URB, POP, REN	URB has the largest negative influence on CO_2 emissions compared to other variables
Asongu et al. (2020)	1980–2014	13 African countries	CO_2 emissions, GDPC, NRT, URB, REN, NEC, and ELE	URB has the least impact on the environment in comparison to other variables in the selected African countries
Xu and Lin (2015)	1980–2012	China	CO_2 emissions, GDP, URB, EI, CT, and PC	URB has a significant effect on CO_2 emissions due to large-scale migration
Nathaniel et al. (2020)	1990–2016	13 MENA countries	EF, REN, NEC, URB, GDP, and FDV	URB contribute to environmental degradation
Ozturk and Al-Mulali et al. (2015)	1996–2012	14 MENA countries	EF, ECO, POL, TO, IND, and URB	URB has a positive effect of EF
Wang et al. (2016)	1980–2009	8 ASEAN countries	URB, CO_2 emissions, Energy use	The significant relationship between URB and CO2 emissions
Wang et al. (2018a)	2000–2014	China	URB, FDI, ENV, and GDPC	URB increases CO_2 emissions
Pata (2018)	197–2014	Turkey	REN, FDV, URB, CO_2 emissions	URB increases environmental degradation
He et al. (2017)	1995 –2013	China	CO_2 emissions, GDP. POP, URB, EI, IND, and T	Kuznets relationship was confirmed between CO_2 emissions and URB for the national sample was confirmed
Saidi and Mbarek (2017)	1990–2013	19 Emerging economies	FDV, Y, URB, FT, and CO_2 emissions	URB shows the strong and positive correlation with Y and CO_2 emissions
Wang et al. (2018b)	1980–2011	170 Different income	URB, economic growth, ECO, and CO_2 emissions	Income levels of the countries affect the relationship between the observed variables
Lin et al. (2017)	1991–2013	53 Countries	CO_2 emissions; POP, GDP, URB, and ECO	Real EDV and URB have little effect on CO_2 emissions in low-income countries.

ELE, electricity energy consumption; *GDP*, gross domestic product; *URB*, urbanization; *REN*, renewable energy; *ECO*, energy consumption; *NRT*, natural resource rent; *NEC*, non-renewable energy consumption; *EI*, energy intensity; *TO*, trade openness; *CT*, cargo turnover; *PC*, private vehicle population; *EF*, ecological footprint; *FDV*, financial development; *IND*, industrial output; *POL*, political stability and conflicts; *RUR*, ruralization; *ENV*, environment; *FDI*, foreign direct investment; *IND*, industrialization; *T*, patents; *POP*, population; *GDPC*, gross domestic product per capita

Table 2 Data description and statistics

Variable		Description and unit						Source
Carbon dioxide emissions (CEM)		Million tonnes of carbon dioxide						BP[2]
Gross domestic product per capita (GDP)		It is a proxy for income per capita and measured as constant 2010 U.S. dollars (it is computed as GDP per capita divided by mid-year country population)						WDI[2]
International tourism arrivals (TOU)		It is the number of international inbound tourists that have traveled to another country other than the usual country of residence						WDI
Energy consumption (ENU)		kg of oil equivalent per capita						WDI
Urbanization rate (URB)		Urban population rate refers to people living in urban areas as (% of total population)						WDI
Common statistics	Mean	Minimum	Maximum	S. dev	Skewness	Kurtosis	Jarque-Bera	
LCEM	4.524	1.908	8.680	1.546	0.475	2.852	26.232*	
LGDP	10.280	8.253	12.661	0.888	0.061	2.717	2.688	
LTOU	15.423	12.830	17.774	− 0.051	− 0.051	2.300	14.198*	
LENU	3.701	0.774	7.750	1.503	0.373	3.074	15.966*	
LURB	4.288	3.924	4.584	0.172	− 0.470	2.217	42.360*	

Observation for the series is 681

Experimental period: 1995–2016

The logarithmic values of real income per capita, carbon emissions, international tourism arrivals, urbanization, and energy consumption are respectively LGDP, LCEM, LTOU, LURB, and LENU. The single asterisk (*) is the 1% statistically significant level. Also, WDI and BP are respective the World Development Indicator of the World Bank, British Petroleum achieving the objective of the study. This is because the QR specifically considers the entire distribution in addition to its desirability to potentially control time-variant issues of heterogeneity and outliers (Asongu and Odhiambo 2019). In specific, except for the LGDP, the lack of evidence of a normal distribution (the null hypothesis of the Jarque-Bera statistics was rejected) for the entire series is significant evidence that supports the QR approach. This is because the QR has a superior advantage of estimating the complete description other than the conditional mean and median distribution (Mosteller and Tukey 1977). Hence, the modification of the conditional mean with fixed effect (FE) implements the QR approach for the current context such that

$$E[\mathrm{LCEM}_{it}|(\mathrm{LGDP}_{it},\mathrm{LTOU}_{it},\mathrm{LENU}_{it}\mathrm{LURB}_{it},),\alpha_i] = \left(\mathrm{LGDP}_{it}^T,\mathrm{LTOU}_{it}^T,\mathrm{LENU}_{it}^T,\mathrm{LURB}_{it}^T\right)\beta+\alpha_i, \quad (2)$$

such that

$$Q_{LCEM_{it}}[\tau|(\mathrm{LGDP}_{it},\mathrm{LTOU}_{IT},\mathrm{LENU}_{it},\mathrm{LURB}_{it}),\alpha_i] = \beta_{1\tau}LGDP_{it}+\beta_{2\tau}LTOU_{it}+\beta_{3\tau}LENU_{it} + \beta_{4\tau}LURB+\alpha_i \quad (3)$$

where time t span from 1995 to 2014 for each OECD member country i: 1, 2, 3…, 31, and given the unobserved country effect α_i.

From the conceptual framework of Koenker and Bassett Jr (1978), the QR extends the conventional least-squares through the application of different conditional quantile functions such that $\widehat{\beta}(\tau)$ in equation 3 is estimated by τththrough the following expression

$$\widehat{\beta}(\tau) = \underset{\beta\in\Re^k}{\arg\min}\left[\sum_{i\in\{i:y_i\geq x_i\beta\}}\tau|y_i-x_i\beta\right]+\sum_{i\in\{i:y_i<x_i\beta\}}(1-\tau)|y_i-x_i\beta|\Big] \quad (4)$$

Indicatively, the parameter size is quantified by τ where $0 < \tau > 1$ such that there is a minimization of the weighted sum of absolute deviations. Hence, the conditional quantile of the CEM (carbon emissions) given an array of the explanatory variables x_i is presented as follows:

$$Q_{\mathrm{CEM}}(\tau|(\mathrm{LGDP_i},\mathrm{LTOU_i},\mathrm{LENU_i},\mathrm{LURB}_i) = (\mathrm{LGDP_i},\mathrm{LTOU_i},\mathrm{LENU_i},\mathrm{LURB}_i)\beta_\tau \quad (5)$$

For this reason, the respective slope parameters for the entire distribution of the LCEM for each category quantile is evaluated in place of the mean of the conditional distribution of the ordinary least square (OLS) and other related regression approaches. However, the current approach has employed the pooled mean group of autoregressive distributed lag (ARDL) and the fully modified OLS (FMOLS) techniques (Pesaran et al. 1999 and Phillips and Hansen 1990 respectively) such that the results are further compared with the quantile regression estimate as depicted in Table 5. Moreover, the lagged of LCEM (outcome variable) is incorporated to remove potential endogeneity with causing the problem of misspecification (Achen 2000).

Table 3 The correlation and cross-sectional dependence test

The correlation of the variables					
Variables	LCEM	LGDP	LTOUR	LENU	LURB
LCEM	1.000				
LGDP	0.368*	1.000			
LTOUR	0.400*	0.084**	1.000		
LENU	0.983*	0.402*	0.390*	1.000	
LURB	0.315*	0.581*	− 0.005	0.327*	1.000
The cross-section dependency test					
Variables	LM test	CD_{LM} test		LM test	CD test
LCEM	3207.310*	27.054*		88.907*	26.85*
LGDP	7927.725*	86.755*		243.700*	86.64*
LTOU	4492.207*	37.928*		131.041*	37.93*
LENU	2836.119*	20.212*		76.736*	20.45*
LURB	7602.015*	30.185*		233.015*	30.03*

The LM and CD are respectively the Lagrange multiplier, cross-sectional dependence. Also, the logarithmic values of carbon emissions, real income per capita, international tourism arrivals, energy consumption, and urbanization are respectively LCEM, LGDP, LTOU, LENU, and LURB. The single asterisk (*) is the 1% statistically significant level

Table 4 Panel unit root test

Panel CIPS	Level		First difference	
	Constant	Trend	Constant	Trend
LCEM	− 1.98	− 2.74**	− 4.55*	− 4.77*
LGDP	− 1.74	− 2.03	− 3.06*	− 3.29*
LTOU	− 2.70*	− 2.72*	− 4.64*	− 4.80*
LENU	− 1.08	− 3.01*	− 4.89*	− 5.06*
LURB	− 0.42	− 1.23	− 1.73	− 2.81*
IPS	Level		First difference	
	Constant	Trend	Constant	Trend
LCEM	0.84	1.67	− 10.53*	− 8.66*
LGDP	− 2.60*	0.63	− 7.12*	− 6.35*
LTOU	2.50	4.36	− 3.816*	2.55
LENU	− 0.80	− 1.39	− 16.31*	− 15.36*
LURB	− 1.94**	− 1.39	− 6.49*	− 56.53*

Variables are stationary at a single asterisk (*) and double asterisks (**) which are respectively for 0.01 and 0.05 significant level. The LCEM, LGDP, LTOU, and LURB are respective logarithmic values of carbon emissions, gross domestic product, tourism (international tourism arrivals), and urbanization

Also, a more robust estimate is produced by employing the bootstrap estimate as indicated in equation (6).

$$Q_{\mathrm{SEI}}(\tau|(\mathrm{HDI}_i, \mathrm{FLF}_i, \mathrm{CEM}_i, \mathrm{URB}_i) = (\mathrm{HDI}_i, \mathrm{FLF}_i, \mathrm{CEM}_i, \mathrm{URB}_i)\beta_\tau \quad (6)$$

Although other details of the estimation procedures are not provided in the current study, the result of the aforementioned QR estimation is presented in Table 5.

The EKC hypothesis

Furthermore, the validity of the EKC hypothesis is tested over the quantiles by employing the same estimation procedure indicated above except that the square of income, i.e., $\mathrm{LGDP}_{\mathrm{sq}}$ is incorporated right from the model (equation 2). The employed QR approach to test the validity of the EKC for all quantiles of the distribution is also complimented with both the ARDL and FMOLS approaches. From all the estimation techniques, the QR, ARDL, and FMOLS models, the peak point of carbon emissions (LCEM) that validates the EKC hypothesis can now be estimated from the estimated corresponding coefficients. Assuming that $\beta_{\mathrm{GDP},\ \tau}$ and $\beta_{\mathrm{GDPsq},\ \tau}$ are the respective coefficients for income and the square of income, then when $\beta_{\mathrm{GDP},\ \tau} > 0$ and $\beta_{\mathrm{GDPsq},\ \tau} < 0$, the EKC hypothesis is valid but if otherwise, there is no evidence of the EKC hypothesis. Moreover, in the case of a valid hypothesis, the estimated peak income or turning point is estimated from $\frac{-\beta_{\mathrm{GDP},\tau}}{2\beta_{\mathrm{GDPsq},\tau}}$.

Robustness test: panel Granger causality

The Dumitrescu and Hurlin's (2012) Granger causality test for heterogeneous non-causality is considered suitable. This is especially because the semi-asymptotic distribution is considered appropriate when N is larger than T (in this case $N = 31$, $T = 26$) as against the asymptotic distribution which is employed when T is larger than N. In any case, Dumitrescu and Hurlin's (2012) Granger causality approach is deemed applicable either when T is larger than N or vice versa. This type of Granger causality approach is robust is built on a vector autoregressive model (VAR) and is considered to be robust even when there is cross-sectional dependency. Thus, by implementing the linear model below:

$$y_{it} = \sum_{k=1}^{K} \lambda_i^{(k)} y_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(k)} x_{i,t-k} + \varepsilon_{i,t} \quad (7)$$

where $\lambda_i^{(k)}$ = autoregressive parameter, K represents the lag length, $\beta_i^{(k)}$ = regression coefficient which is permitted to vary within the groups, the causality test is normally distributed and did allow for heterogeneity. Thus, the null and alternative hypotheses for homogenous non-stationary causality are stated as follows:

$$H_0 : \beta_i = 0\ldots\ldots\forall_i = 1, \ldots..N$$
$$H_1 : \beta_i = 0\ldots\ldots\forall_i = 1, \ldots..N_1$$
$$\beta_i \neq 0\ldots\ldots\forall_i = N_1 + 1, N_1 + 2, \ldots.N$$

where the unknown parameter is denoted by N_1 , which satisfies the condition $0 \leq N_1/N < 1$. Consequently, $N_1/N <$ 1 is an expected estimate. But, when $N_1 = N$, then the evidence presents that across cross-sections, there is no causality, thus translating to failure to reject the null of homogenous non-stationary causality. Moreover, $N_1 = 0$ presents a causal nexus in the macro panel approach. In this case, the result of the Granger causality presented in Table 6.

Results and discussion

Regarding the illustrated quantile regression of Table 5, there is statically significant evidence that an increase in per capita real income is responsible for the reduction of environmental degradation along the quantiles. Except for the insignificant impact of GDP on CEM in the 0.50th quantile, the increase in per capita income level has a desirable impact on the quality of the environment but this desirability effect diminishes toward the upper quantile. For instance, a 1% increase in real income is responsible for a 0.405% decrease in carbon emissions at the 0.05th quantile while the impact becomes 0.024% in the 0.90th quantile. Interestingly, both estimates of the PMG and FMOLS affirm a negative relationship between CEM and GDP but the FMOLS result is insignificant. This evidence is further corroborated by the one-way significant Granger causality from GDP to CEM in the examined panel (see Table 6). In corroborating this evidence, the study of Iwata et al. (2011) found a decreasing relationship between the growth rate of CEM and income for the OECD countries.

Moreover, illustration from Table 5 shows that the validation of the EKC hypothesis for the panel of 31 OECD countries is varied across the quantile. Specifically, while the 0.05th and 0.10th quantile validates the (inverted U-shaped) EKC hypothesis, a U-shaped evidence is therefore implied for the 0.25th, 0.50th, 0.75th, and the 0.90th quantiles. The implication is that the growth in the square in the value of per capita will only cause a huge decrease in environmental degradation at the lowest quantile of CEM, i.e., the 0.05th quantile while such a desirable impact fades a little in the 0.10th quantile. Additionally, in the other quantiles (the 0.25th, 0.50th, 0.75th, and the 0.90th quantiles), the growth of the square in per capita income is detrimental to the quality of the environment. In confirming this result, the validation of

Table 5 The ordinary least square and quantile regression with (100) bootstrapping dependent variable = CEM

Quantile regression								
Variable	PMG	FMOLS	5th	10th	25th	50th	75th	90th
LGDP	− 0.021***	− 0.023	− 0.405*	− 0.347*	− 0.104*	− 0.009	− 0.020**	− 0.024
LTOU	− 0.040*	− 0.031*	0.130**	0.140*	0.023*	0.013**	− 1.59E-06	0.046*
LENU	1.026*	1.000*	1.173*	1.130*	1.065*	1.013*	0.984*	0.983*
LURP	0.610*	− 0.416*	0.036	0.037	0.005	0.140***	0.372*	0.221*
Constant		0.182**	1.646	1.143	1.176*	0.094	− 1.350	− 0.227
R^2		0.999	0.745	0.759	0.817	0.851	0.875	0.886
SMD			42.801	77.057	114.432	123.701	89.243	44.900
Testing the EKC								
LGDPsq	− 0.021*	− 0.001	-0.193*	− 0.160*	0.029*	0.027*	0.008	0.019
LGDP	0.350**	− 0.012	3.600*	2.900*	− 0.661*	− 0.567*	− 0.186	− 0.426
LTOU	− 0.030*	− 0.031*	0.021	0.500**	0.028*	0.025*	0.0005	0.040*
LENU	1.061*	1.008*	1.201*	1.137*	1.061*	1.011*	0.984*	0.981*
LURP	0.459*	− 0.411*	− 0.908*	− 0.474	− 0.014	0.109***	0.383*	0.234*

FMOLS, PMG, MSD, EKC are respectively the minimum sum of fully-modified ordinary least square, pooled mean group, deviation, and the environmental Kuznets curve. The logarithmic values of real income per capita, carbon emissions, international tourism arrivals, urbanization, and energy consumption are respectively LGDP, LCEM, LTOU, LURB, and LENU. The single asterisk (*), double asterisks (**), and triple asterisks (***) are respectively the 1%, 5%, and 10% statistical significant level

the EKC hypothesis for the panel of OECD countries from the extant studies has remained divided. While the evidence from a handful of studies supports the validity of the EKC hypothesis in the panel of OECD member countries (Galeotti et al. 2006; Jebli et al. 2016; Zaman et al. 2016), other studies have shown either the lack of evidence supporting the EKC hypothesis or valid evidence of an *N*-shaped or inverted *N*-shaped hypothesis for the panel of OECD countries (Iwata et al. 2011; Özokcu and Özdemir 2017).

In addition, there is statistically significant evidence that the increase in the number of international tourism arrivals (TOU) to the panel of OECD countries is responsible for more emissions of carbon dioxide (see the PMG and FMOLS in Table 5). Although this evidence differs from that of the quantile regression, the impact of TOU on carbon emissions is not desirable with a decreasing impact across the quantiles. For instance, a 1% increase in TOU is responsible for a 0.13% increase in CEM in the lowest quantile (0.05th) but the impact decreased to 0.046% in the 0.90th quantile. We also found significant evidence of bidirectional Granger causality relationship between TOU and CEM while a one-way directional and significant impact is observed from urbanization to international tourism arrivals. In previous studies such as Zaman et al. (2016) and Lasisi et al. (2020), the relationship between tourism performance and carbon emissions is found to be significant. Interestingly, the current study found a similar relationship between urbanization and carbon emissions across the quantiles. Specifically, an increase in urbanization in the panel of OECD countries is responsible for an increase in carbon emissions at a high rate in the lowest (0.05th) quantile and the highest rate in the upper (0.90th) quantile.

Furthermore, the study found that energy usage in the panel of OECD countries is a significant determinant of environmental degradation. While both the PMG and FMOLS estimates illustrate a positive relationship between energy consumption and environmental damage, the relationship is also positive but decreasing across the quantiles. Specifically, the

Table 6 Dumitrescu and Hurlin (2012) Granger causality

Causality	*z*-bar	Causality	*z*-bar
lcem → lgdp	2.521	lgdp → lcem	7.822*
lncem → ltou	4.300*	ltou → lcem	6.037*
lcem → lenu	3.804*	lenu → lcem	3.139**
lcem → lurb	2.050	lurb → lcem	6.140*
ltou → lgdp	4.963*	lgdp → ltou	3.807
lenu → lgdp	3.178***	lgdp → lenu	4.880*
lurb → lgdp	3.7333*	lgdp → lurb	5.676*
lenu → ltou	2.952	ltou → lenu	3.549**
lurb → ltou	5.534*	ltou → lurb	4.124*
lurb → lenu	5.619*	lenu → lurb	2.644

The single asterisk (*), double asterisks (**), and triple asterisks (***) are respectively for 0.01, 0.05, and 0.1 significant level. The LCEM, LGDP, LTOU, and LURB are respective logarithmic values of carbon emissions, gross domestic product, tourism (international tourism arrivals), and urbanization consumption of energy in the OECD countries is responsible for greater deteriorating environmental damage in the lowest (0.05th) quantile but the damaging impact subsides in the upper (0.90th) quantile. Similarly, the result of the second model (with EKC) in the lower part of Table 5 further affirms that the impact of energy consumption on the environment is damaging but the intensity of such impact decreases across the quantile. In addition, there is a two-way Granger causality nexus between energy usage and carbon emissions in the examined panel (see Table 6). In general, both the Granger causality and the quantification of the impact of energy consumption on carbon emissions have been examined in extant studies (Jebli et al. 2016; Özokcu and Özdemir 2017; Zaman et al. 2016).

The per capita income turning points are computed from $\frac{-\beta_{GDP,\tau}}{2\beta_{GDPsq,\tau}}$ by using the estimates of per capita income (GDP) and the square per capita income (GDPsq) of Table 5. As such, the quantiles turning point representations for 0.05th, 0.10th, 0.25th, 0.50th, 0.75th, and 0.90th are respectively 11, 271.13 USD, 8, 604.15 USD, 89, 321.72 USD, 36, 315.50 USD, 111, 865.41 USD, and 73, 865.41 USD. However, statistical significance is only reported for 0.05th to 0.50th quantiles, meaning that the significant turning points are 11, 271.13 USD, 8, 604.15 USD, 89, 321.72 USD, and 36, 315.50 USD.

Conclusion and policy matters

Although the environmental sustainability of the OECD countries has been considered under varying circumstances, the current study advanced a handful of the related extant studies (Galeotti et al. 2006; Iwata et al. 2011; Jebli et al. 2016; Özokcu and Özdemir 2017; Zaman et al. 2016) with some element of novelty. While employing an updated period (1995–2016), the current study employed the panel quantile approach to examine the determinants of environmental sustainability for the first time. Interestingly, as per capita income grows, environmental quality is increasingly damaged across the quantiles but the damage caused by the per capita income is minimized at the upper quantile. In addition, while using the panel quantile approach, the EKC hypothesis is further investigated for the OECD countries. Thus, the result of the investigation validates the EKC (inverted *U*-shaped) hypothesis only in the first two (the 0.05th and 0.10th) quantiles while the *U*-shaped (insignificant evidence of EKC) hypothesis is validated in the remaining (0.25th, 0.50th, 0.75th, and the 0.90th) quantiles. Moreover, the impacts of international tourism arrivals, energy consumption, and urbanization on carbon emissions in the panel of the OECD countries are all statistically positive and significant. Illustratively, the aforementioned impacts (of energy use, tourism arrivals, and urbanization) on the environmental quality vary across the quantiles while the associated Granger causalities with carbon emissions are found to be statistically significant. Indicatively, this result suggests that the sustainable development drive in OECD countries is dependent on the implementation of targeted policy mechanisms.

Policy mechanism

Another important part of this study is its policy relevance through the instruments of government, public-private partnerships, and other affiliated agencies. Foremost, the variability of the impact of the per capita income and the square of per capita income on carbon emissions across the quantile is an illustration of both the degree of the income gap and the possibility of carbon out-sourcing among the examined countries. Thus, the governments of the OECD member countries especially the low-income member countries should further adapt rigorous economic policies that are capable of improving and closing the income gap with the advanced economies. However, such economic policies should be sustainable especially through the adaptation of the energy transition policy of the country's main economic sectors such as tourism, transportation, industrial, and manufacturing.

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Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Compliance with ethical standards

Competing interests The authors declare that they have no competing interests.

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