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Analyzing long lasting effects of environmental policies: Evidence from low, middle and high income economies

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ABSTRACT

This study investigates whether or not environmental policies have long lasting effects by analyzing stochastic properties of ecological footprint that recently attracts a great attention and is accepted as a broader measure of the environmental degradation in the literature. To this end, countries are classified by income groups and the panel KSS unit root test alongside the SPSM procedure are utilized based on the annual data from 1961 to 2013. The empirical results show that ecological footprint has stationary process for all high-income countries and for about the half of the low-income and upper-middle income economies, whereas non-stationarity is verified for the lower-middle income economies. Crucial policy implications are further discussed.

1. Introduction

Stochastic behaviors of a variable yield important policy implications. For instance, once a series follows a nonstationary process, shocks to such series will have long lasting effects; conversely, if a series is stationary, shocks will have transitory effects (Lee & Chang, 2008). In addition, stationarity is of great importance because knowledge on the nature of shocks has an important consideration in policy determination (Dogan, 2016; Smyth & Narayan, 2015). Referring to Mishra, Sharma, and Smyth, (2009) and Hasanov and Telatar (2011), stationarity helps researchers to understand the evolutionary path of a series based on its past behavior and policymakers formulate appropriate policies for the future. Moreover, Belbute and Pereira (2017) postulate that measuring the persistence of a variable provides insightful perspectives for the design, implementation and the effectiveness of environmental policies reducing the dependence of economies on environmentally damaging practices. Furthermore, time series analyses should consider the stationarity properties of series so as to ascertain the long-run relationship (cointegration) among the variables (Phillips & Sul, 2007). Last, stationarity for a panel series provides information about the convergence hypothesis (Islam, 2003; Strazicich & List, 2003; Westerlund & Basher, 2008). In the context of environment, empirical evidence in favor of convergence implies that countries will have the same quality or degradation level over time (Brock & Taylor, 2003; Herrerias, 2013). Besides, convergence across countries indicates that common environmental policies should be implemented (Acaravcı & Erdogan, 2016; Presno, Landajo, & Fernández González, 2015; Romero-Ávila, 2008; Westerlund & Basher, 2008).

As a result of severe environmental threats such as global warming and climate change, the global environmental policies have gained great importance over a half century in order to achieve sustainable development goals (United Nations, 2015). The Kyoto Protocol and the Paris Climate Agreement carried out under the guidance of the United Nations try to find solution for the threats at the global level although there are some deficiencies and unwillingness of some countries to struggle with the environmental threats. As an important deficiency, countries solely focus on curbing CO_2 emissions level and ignore other deterioration sources. However, other forms of environmental degradation such as degradation in soil stock, forestry stock, mining stock and oil stock should also be considered (Arrow et al., 1995). To support this argument, Stern (2014) finds that CO_2 emissions level might have declined in the developed countries, whereas the levels of some other types of pollution might be still high.

It is thus clear that the empirical results may mislead policymakers if CO_2 emissions are solely used as a proxy for environmental degradation. Hence, a more comprehensive measure of environmental degradation levels of countries is required to consider genuine deteriorations that adversely affect ecosystem and sustainable environment (World Bank, 1995). In line with this purpose, ecological footprint (henceforth, EF) developed by Rees (1992); Wackernagel (1994) and

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Wackernagel and Rees (1996) can potentially satisfy the need for extensive monitoring of the environment because it takes six components into consideration: Cropland, Grazing Land, Fishing Grounds, Forest Land, Built-up Land and CO_2 emissions. EF also shows an anthropogenic pressure that has been labeled on the environment (York, Rosa, & Dietz, 2004; Dietz, Rosa, & York, 2007; Jorgenson & Burns, 2007; Jorgenson & Rice, 2005; Jorgenson, 2003; Rothman, 1998; Vackar, 2012; York, Rosa, & Dietz, 2003; York, Rosa, & Dietz, 2009) and measures the direct and indirect impacts of production and consumption activities on the environment (McDonald & Patterson, 2004).

Moreover, EF can be used to make forecasts for natural resource consumption limits, international distribution of the world resources and the sustainability of resource consumption in the world (Borucke et al., 2013). Therefore, It can be considered as an important tool to manage natural resources efficiently (Zhang, Dzakpasu, Chen, & Wang, 2017). Because EF provides a ground to set goals, identify options for action and to track progress toward stated goals, it is also accepted as a strong communication tool and useful environmental performance indicator by the European Environment Agency (EEA, 2010), the European Union, European Commission (Best et al., 2008) and the United Nations (UNDP, 2014). Due to its fundamental roles in effectively and comprehensively measuring the environmental impacts of the human activities, EF has recently been considered as an indicator of the environmental pressure by recent studies (Acar & Aşıcı, 2017; Charfeddine & Mrabet, 2017; Charfeddine, 2017; Isman et al., 2017; Lu & Chen, 2017; Mrabet & Alsamara, 2017; Ozturk, Al-Mulali, & Sboori, 2016; Rashid et al., 2018; Uddin, Salahuddin, Alam, & Gow, 2017; Ulucak & Lin, 2017; Wang, Yang, Yin, & Zhang, 2017; Ulucak & Apergis, 2018).

Based on the aforementioned explanations, this paper aims to examine the stochastic behavior of EF for 113 countries categorized by four income groups; high-income, upper-middle income, lower-middle income and low-income. For this purpose, we utilize several unit root tests because the most common method is the use of unit root tests in order to effectively determine the stochastic behaviors of a time-series. Overall, the main potential contributions of the paper are threefold: i) Considering the aforementioned importance and features of EF, this study relies on a better and broader data compared to other indicators such as CO_2 emissions; ii) This is the first study that analyzes the stationarity process of countries based on income-groups. It is also worth to note that-to the best of our knowledge-only two studies, Ulucak and Lin (2017); Solarin and Bello (2018), have so far used EF data for this purpose; iii) This study uses both first and second-generation panel unit root tests; thus, the empirical results are robust and strong. According to Smyth and Narayan (2015), studies mostly rely on the first-generation panel unit root tests that likely suffer from the assumption of cross sectional dependence.

The remainder of the paper is organized as follows. Section 2 provides a brief literature review, Section 3 explains the data and methodology, Section 4 covers the empirical results and discussions, and the last Section concludes the study with policy recommendations.

2. Literature review

A number of studies utilized CO_2 emissions as an indicator of environmental quality for different research purposes (Apergis & Ozturk, 2015; Kasman & Duman, 2015; Shahbaz, Solarin, Sbia, & Bibi, 2015; Tang & Tan, 2015; Zhang & Da, 2015).

Some of the previous studies that analyzed the behavior of CO_2 emissions obtained evidence of stationarity (Aldy, 2006; Chang & Lee, 2008; Ezcurra, 2007; List, 1999; Nguyen-Van, 2005; Panopoulou & Pantelidis, 2007; Strazicich & List, 2003; Westerlund & Basher, 2008; Romero-Ávila, 2008; Camarero, Picazo-Tadeo, & Tamarit, 2008; Lee & Chang, 2008; Lee, Chang, & Chen, 2008; Barassi, Cole, & Elliott, 2008; Lee & Chang, 2009; Panopoulou & Pantelidis, 2009; Brock & Taylor, 2010; Jobert, Karanfil, & Tykhonenko, 2010; Barassi, Cole, & Elliott, 2011; Christidou, Panagiotidis, & Sharma, 2013; Li & Lin, 2013; Jordá & Remuzgo, 2013; Yavuz & Yilanci, 2013; Zhao, Burnett, & Lacombe, 2014; Solarin, 2014; Brännlund, Lundgren, & Söderholm, 2014; Anoruo & DiPietro, 2014; Li, Tang, & Chang, 2014; Ahmed, Khan, Bibi, & Zakaria, 2016; Sun, Su, & Shao, 2016; Robalino-López, García-Ramos, Golpe, & Mena-Nieto, 2016; Tiwari, Kyophilavong, & Albulescu, 2016; Belbute & Pereira, 2017). The stationarity result is an indication that shocks to CO_2 emissions will have temporary effects. So, policy suggestions are likely not effective because innovations and contributions do not have permanent effects; thus, air pollution will turn to its standard line.

On the other hand, a number of studies found that CO_2 emissions follow a unit root process (Akbostancı, Turut-Asık, & Tunc, 2009; Aldy, 2006; Aslanidis, 2009; Barassi et al., 2008; Camarero, Mendoza, & Ordoñez, 2011; Criado & Grether, 2011; Fodha & Zaghdoud, 2010; Galeotti, Lanza, & Pauli, 2006; Herrerias, 2013; Jaunky, 2011; Lanne & Liski, 2003; Lee & Chang, 2008; Lee & Lee, 2009; Li & Lin, 2013; Magazzino, 2014; Presno et al., 2015; Richmond & Kaufmann, 2006; Yamazaki, Tian, & Doko Tchatoka, 2014). If per capita carbon emission series follow a unit root process, then the shocks affecting the series will have permanent effects. In this case, the administrative policy of government should adopt necessary targets to revert per capita emissions series back to its original mean when the series deviates from its trend path (Lee & Lee, 2009).

In addition to the above-mentioned studies, several studies use fractional integration methods to test for the time series dynamics of environmental degradation indicators. By using the fractional integration method to check for the stationarity of air pollution (including CO) in four Mega-cities of China, Chen, Barros, and Gil-Alana, (2016) state that orders of integration are substantially different from zero and one. Barros, Gil-Alana, and De Gracia, (2016) find that orders of integration of CO_2 emissions are greater than one by employing the fractional integration technique on global data from 1751 to 2009. Gil-Alana, Cunado, and Gupta, (2017) analyze the unit root process of CO_2 emissions in BRICS and G7 countries and show that the orders of integration of CO_2 emissions are equal or greater than one in all countries except for the USA, the UK and Germany. Besides, Gil-Alana and Trani (2018) investigate the stationarity of CO_2 emissions in the EU countries by using advanced econometric approaches in time series and reveal that order of integration of CO_2 emissions significantly exceed I(1).

In the arguments of Al-Mulali, Weng-Wai, Sheau-Ting, and Mohammed, (2015), CO_2 emissions make only a small part of the total environmental damage caused by high energy demand. Conversely, EF indicates anthropogenic pressure on the environment (2004, Dietz et al., 2007; Jorgenson & Burns, 2007; Jorgenson & Rice, 2005; Jorgenson, 2003; Rothman, 1998; Vackar, 2012; York et al., 2003, 2009). Due to its crucial roles in effectively and comprehensively measuring the environmental impacts stemming from human activities, EF has been employed by many researchers as an indicator of environmental degradation (Bagliani, Bravo, & Dalmazzone, 2008; Guan, Li, & Wang, 2008; Caviglia-Harris, Chambers, & Kahn, 2009; Chambers & Guo, 2009; Mostafa, 2010; Zhang, Jia, & Liu, 2010; Wang, Zhou, Zhou, & Wang, 2011; Yiqing, Ting, & Yun, 2012; Galli et al., 2012; Wang, Kang, Wu, & Xiao, 2013; Hervieux & Darné, 2015; Aşıcı & Acar, 2016; Ozturk et al., 2016; Acar & Aşıcı, 2017; Charfeddine & Mrabet, 2017; Ulucak & Apergis, 2018).

It is hereby key to note that no studies directly analyze the stationarity of EF exceptions with Ulucak and Lin (2017) that focuses on the case of the USA, Solarin and Bello (2018) that analyzes 128 countries by using time series methodologies. To understand the stochastic behaviors of EF series for countries classified by income groups and to consider country specific effects, this study aims at analyzing whether shocks to EF are permanent or temporary for over 100 countries based on different panel unit root tests for the period 1961-2013.

3. Data and methodology

3.1. Data

This study includes annual per capita EF (measured in global hectare) data provided by Global Footprint Network (GFN). Sample consists of countries classified into four groups based on their income levels: thirty high-income countries, twenty eight upper-middle income countries, twenty nine lower-middle income countries and twenty six low-income countries. We used the World Bank's (1995) classification of countries by income[1]. Time period is from 1961 to 2013. The selection of time period and countries is dictated by data availability. We utilize EF in its natural logarithmic form. the GFN defines EF as a "measure of how much area of biologically productive land and water an individual, population, or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices."[2] EF is the total value of six subcomponents; namely, Built-Up Land Footprint, Carbon Footprint, Cropland Footprint, Fishing Grounds Footprint, Forest Products Footprint, and Grazing Land Footprint. Conceptually, EF measures the burden of consumption and production activities on the nature (Bartelmus, 2008) and how much biological productive capacities of the planet is demanded by people (Kitzes & Wackernagel, 2009). As countries increase their income level based on rises in production and consumption, environmental degradation and natural resource exploitation increase as well (Acar & Aşıcı, 2016). On the other hand, the environmental Kuznets curve hypothesis, introduced by Grossman and Krueger (1991) and 1995), claims that environmental degradation starts to decrease after per capita income reaches a turning point. Because citizens in high income countries have more environmental awareness, they demand ecofriendly goods and environmental regulations strictly practiced in these countries. Therefore, income level is more important in the analysis of EF (Acar & Aşıcı, 2016; Al-Mulali et al. 2015; Ozturk et al., 2016; Ulucak & Bilgili, 2018).

Before proceeding to the empirical analyses, some summary statistics of the data are provided in Table 1. The mean EF ranges from 5.6857 in high-income countries to 1.1105 in low-income countries. Besides, the maximum and the minimum values of EF belong to high-income countries. Among high-income countries, Luxembourg has the highest and the South Korea has the lowest EF values. In addition, low-income countries have the least variation (i.e., the least standard deviation) in EF (0.4937) while the high-income countries have the highest variation (2.6533).

3.2. Methodology

We combine three methodological approaches: First, the Panel KSS unit root test developed by Ucar and Omay (UO hereafter) (2009), second, the Fourier function and third, the Sequential Panel Selection Method (SPSM) proposed by Chortareas and Kapetanios (2009), to test for the unit root process in the per capita EF series. By doing this, we allow for nonlinearity in the data generating process to analyze the smooth, unknown and gradual processes in structural breaks in data and to categorize countries based on the time series features of their per capita EF series. Therefore, we explain each of those three methodological approaches below. We explain the Panel KSS test of Ucar and Omay (2009) in Equations 1–5 and the extended version of Panel KSS test with a Fourier function in Eq. (6).

[1] World Bank utilizes the gross national income (GNI) per capita, in U.S. dollars, converted from local currency using the World Bank Atlas method while classifying countries. See, for a detailed calculation method, https://datahelpdesk.worldbank.org/knowledgebase/articles/378832-what-is-the-world-bank-atlas-method

[2] http://data.footprintnetwork.org/#/abouttheData

Table 1
Summary statistics of EF (in level).

Countries	Obs.	Mean	Median	Maximum	Minimum	Std. Dev
High-income	1590	5.6857	5.4340	17.1908	0.0007	2.6533
Upper-middle income	1484	2.313	2.2105	5.4923	0.5131	0.9894
Lower-middle income	1537	1.3883	1.1858	6.5016	0.5099	0.8199
Low-income countries	1378	1.1105	1.1448	2.5396	0.0014	0.4937

Ucar and Omay (2009) developed a nonlinear heterogeneous panel unit root test based on the nonlinear time series framework of Kapetanios, Shin and Snell (KSS, 2003) and the panel unit root testing procedure of Im, Pesaran and Shin (IPS, 2003). Kapetanios et al. (2003) unit root test depends on detecting the presence of nonstationarity against a nonlinear but globally stationary exponential smooth-transition autoregressive (ESTAR) process. The model could be defined as follows:

$$\Delta Y_t = \gamma Y_{t-1}\{1 - \exp(-\theta Y_{t-1}^2)\} + v_t \tag{1}$$

where Y_t is the variable of interest (i.e., per capita EF); v_t is an independent identically distributed error with zero mean and constant variance and $\theta > 0$ is the transition parameter of the ESTAR model and indicates the speed of transition. However, this testing framework has a problem since γ_t is not defined under the null hypothesis. Therefore, Kapetanios et al., 2003 utilized a first-order Taylor series approximation for $\{1 - \exp(-\theta Y_{t-1}^2)\}$ under the null hypothesis (H_0: $\gamma = 0$) and approximated Eq. (1) by using the auxiliary regression defined in Eq. (2).

$$\Delta Y_t = \xi + \delta Y_{t-1}^3 + \textstyle\sum_{i=1}^{k} \theta_i \Delta Y_{t-i} + v_t, \quad t = 1, 2, \ldots\ldots, \mathrm{T} \tag{2}$$

Herein, the null and the alternative hypotheses are expressed as $\delta = 0$ (non-stationarity) against $\delta < 0$ (nonlinear ESTAR stationarity). Ucar and Omay (2009) developed a nonlinear panel data unit root test based on Eq. (1). Their testing procedure depends on the following regression:

$$\Delta Y_{i,t} = \gamma_i Y_{i,t-1}\{1 - \exp(-\theta_i Y_{i,t-1}^2)\} + v_{i,t} \tag{3}$$

Ucar and Omay (2009) also employed a first-order Taylor series approximation to the panel ESTAR model around $\theta_i = 0$ for all i and obtained the following auxiliary regression:

$$\Delta Y_{i,t} = \varsigma_i + \delta_i Y_{i,t-1}^3 + \sum_{j=1}^{k} \theta_{i,j} \Delta Y_{i,t-j} + v_{i,t} \tag{4}$$

where Y_t is the variable of interest (i.e., per capita EF) and $\delta_i = \theta_i \gamma_i$. Based on Eq. (4), they have formulated the following null and alternative hypotheses for the unit root testing procedure:

$$H_0\text{: } \delta_i = 0, \text{ for all i (linear nonstationarity)}$$
$$H_1\text{: } \delta_i = 0, \text{ for some i (nonlinear stationarity)} \tag{5}$$

Along with the panel KSS unit root test, we also take structural breaks into account since Perron (1989) stated that if there is a structural break, the power to reject a unit root decreases when the stationary alternative is true and the structural break is ignored. However, as indicated by Prodan (2008), it can be quite difficult to properly estimate the number and the magnitudes of multiple breaks, particularly when the breaks are of opposite sign. Therefore, unit root tests with a Fourier function have gained popularity in the recent literature. A number of scholars, e.g. Becker, Enders, and Lee, (2006); Enders and Lee (2012) and Gallant (1981) proposed that the behavior of an unknown function can be captured by a Fourier approximation even if the function itself is not periodic. Besides, Enders and Holt (2012) suggested that many breaks known or unknown in a series can be captured by utilizing a small number of low-frequency components from a

Fourier approximation. Also, breaks should be approximated as smooth and gradual processes when structural breaks take the form of large swings, which cannot be captured well using only dummies (Leybourne, Newbold, & Vougas, 1998). In Fourier based unit root tests, the specification problem is just transformed into including the appropriate frequency components into the regression instead of selecting the specific break dates, the number of breaks, and the form of the breaks (Enders & Lee, 2012). Therefore, Eq. (4) can be extended with a Fourier function which does not require a priori knowledge on date, number, and form of breaks. Thereby, Eq. (6) is obtained as:

$$\Delta Y_{i,t} = \varsigma_i + \delta_i Y_{i,t-1}^3 + \sum_{j=1}^{k} \theta_{i,j}\Delta Y_{i,t-j} + a_{i,1}\sin\left(\frac{2\pi kt}{T}\right) + b_{i,1}\cos\left(\frac{2\pi kt}{T}\right) + \varepsilon_{i,t} \tag{6}$$

where Y_t is the variable of interest (i.e., per capita EF), $t = 1, 2, ..., T$, k indicates the number of frequency selected for the approximation, $a_{i,1}\sin(\frac{2\pi kt}{T}) + b_{i,1}\cos(\frac{2\pi kt}{T})$ is the Fourier function that captures the number of smooth breaks through minimizing the residual sum of squares, and the π value is 3.1416. Fourier function can approximate absolutely integral functions to any desired degree of accuracy (Liu, 2013). Then, the hypothesis of $a_{i,1} = b_{i,1} = 0$ is tested with a simple F test and the rejection of $a_{i,1} = b_{i,1} = 0$ provides evidence for including the Fourier term into the testing regression.

Additionally, panel-based unit root tests cannot determine the combination of stationary and non-stationary series in a panel setting because they are joint tests of a unit root for all panel members (see Liu, 2013). Therefore, this study employs the Sequential Panel Selection Method (SPSM) proposed by Chortareas and Kapetanios (2009) to identify how many and which countries in each panel are stationary. Each step of the SPSM is as follows:

1 The panel KSS test is first applied on all EF series in each country panel. The process is stopped if the unit root null hypothesis cannot be rejected and all series are accepted as nonstationary. However, if the null hypothesis is rejected, the stage two is followed.
2 The series (i.e. country) with the minimum KSS statistic is excluded as it is stationary.
3 Step one is repeated for the remaining series or the process is stopped if all series are excluded from the panel. Thereby, we can separate whole panel into a set of stationary countries and a set of nonstationary countries.

4. Empirical results

4.1. Results from univariate unit root tests

As a comparison purpose, we first employ several univariate and panel-based unit root tests before applying the Panel KSS unit root test. In this respect, three traditional univariate unit root tests—augmented Dickey and Fuller (1979); Phillips and Perron (1988) and Kwiatkowski, Phillips, Schmidt, and Shin, 1992 —are utilized. Besides, two nonlinear unit root tests— Kapetanios et al. (2003) and Kruse (2011)) — are used. Their results (related test statistics and critical values) are reported in Tables A1–A4 in the Appendix.

ADF and PP tests provided evidence for the stationarity of EF in eight high-income countries (Australia, Canada, Israel, South Korea, Luxembourg, New Zealand, Sweden and Switzerland) while the KPSS unit root test confirmed the stationarity of EF in 10 high-income countries (Australia, Austria, Belgium, Israel, Netherlands, New Zealand, Portugal, Spain, Sweden and United Kingdom). Regarding the nonlinear univariate unit root tests, the KSS unit root test for seven high-income countries (Australia, Canada, South Korea, Luxembourg, New Zealand, Sweden and Switzerland) and the ESTAR unit root test for eight high-income countries (Australia, Canada, Greece, South Korea, Luxembourg, New Zealand, Sweden and Switzerland) supported stationarity of EF.

For the panel of upper-middle income countries, EF was found to be stationary for three countries (Costa Rica, Fiji and Turkey) in case of the ADF test, for five countries in case of the PP test (Albania, Costa Rica, Fiji, Mexico and Turkey) and for nine countries in case of the KPSS test (Argentina, Costa Rica, Dominican Republic, Malaysia, Mexico, Panama, Thailand, Turkey and Venezuela). Concerning the nonlinear unit root tests, the KSS and ESTAR tests confirmed stationarity of EF only in two upper-middle income countries (i.e., Costa Rica and Venezuela). Regarding the panel of lower-middle income countries, five countries (Indonesia, Morocco, Nicaragua, Sao Tome and Principe and Tunisia) in the ADF test, seven countries (Egypt, Indonesia, Morocco, Nicaragua, Sao Tome and Principe, Syrian Arab Republic and Tunisia) in the PP test and nine countries (Bolivia, Congo, Egypt, Jordan, Nigeria, Pakistan, Philippines, Sao Tome and Principe and Sudan) in the KPSS test were found to have stationary EF. Both the nonlinear KSS and ESTAR unit root tests supported the evidence of stationarity in EF for six countries.[3]

Finally, eight countries in the low-income countries panel (Burkina Faso, Gambia, Haiti, Mozambique, Niger, Senegal, Tanzania and Zimbabwe) in both the ADF and PP unit root tests, seven countries (Congo Democratic Republic, Gambia, Madagascar, Mozambique, Niger, Rwanda and Tanzania) in the KPSS test, nine countries (Burkina Faso, Gambia, Guinea, Mozambique, Niger, Rwanda, Senegal, Tanzania and Zimbabwe) in the KSS test and eight countries (Burkina Faso, Gambia, Guinea, Mozambique, Niger, Senegal, Tanzania and Zimbabwe) in the ESTAR test appeared to have stationary EF. Overall, the results from the linear and nonlinear univariate unit root tests provided more evidence of stationarity for the high- and the low-income countries. However, in general, the univariate unit root test results indicated that EF follows a unit root process in most countries.

4.2. Results from panel-based unit root tests

Univariate unit root tests used in this study are likely to be inefficient as they ignore the cross-section dimension of data and do not allow for structural breaks. Therefore, we applied a number of first and second-generation panel unit root tests so as to produce more efficient results. Panel unit root tests increase the power of the order of integration analysis by combining the cross-sectional and temporal dimensions of data (see Liu, 2013).

Results of the panel unit root tests were tabulated in Tables 2 and 3. We applied four first-generation panel unit root tests developed by Im, Pesaran, and Shin, 2003; Levin, Lin, and Chu, 2002; Maddala and Wu (1999) and Choi (2001). In Table 2, we tabulated the results of test statistics with their probabilities values. As seen in Table 2, for the high-income countries panel, all panel unit root tests indicated that EF was stationary. For the low-income countries panel, panel unit root tests except with the Levin et al. (2002) test proved that EF is stationary. However, for the upper-middle income countries panel, only Choi (2001) test revealed evidence of stationarity, whereas all four panel unit root tests confirmed nonstationarity of EF for the lower-middle income countries panel.

However, there is an insufficiency of first-generation panel unit root tests since they do not allow for cross-sectional dependence among panel members. Thus, we used four second-generation panel unit root tests —Bai and Ng (BN, 2004), Moon and Perron (MP, 2004), Choi (2002) and Pesaran (CIPS, 2007)—allowing for cross-sectional dependence among countries. Cross-sectional dependence is a crucial issue, in particular, if panel consists of countries in a similar category such as developed countries, emerging countries, high-income countries or

[3] Jordan, Nicaragua, Philippines, Syrian Arab Republic, Tunisia, and Yemen were stationary in the KSS test while Egypt, Jordan, Nicaragua, Philippines, Syrian Arab Republic and Yemen were stationary in the ESTAR test.

Table 2
Results from the first-generation panel unit root tests.

Countries	IPS	LLC	ADF-Fisher	PP-Fisher
High-income panel	−6.908[a]	−8.038[a]	166.876[a]	183.691[a]
	(0.000)	(0.000)	(0.000)	(0.000)
Upper-middle income panel	0.12514	−1.1641	53.548	71.967[c]
	(0.549)	(0.122)	(0.568)	(0.074)
Lower-middle income panel	2.926	1.406	36.930	39.373
	(0.998)	(0.920)	(0.986)	(0.971)
Low-income panel	−1.344[c]	−1.147	83.114[a]	94.898[a]
	(0.089)	(0.125)	(0.003)	(0.000)

Notes: Constant term was included into model. Schwarz information criterion was used to select the lag length; Bartlett and Newey-West were used in spectral estimation and bandwidth selection, respectively. [a], [b] and [c] indicate rejection of the unit root null hypothesis at 1%, 5% and 10% significance levels, respectively. Probabilities are reported in parentheses.

transition countries. Also, as stated by O'Connell (1998), failure to consider contemporaneous correlations among data creates bias in the panel-based unit root tests towards rejecting the join unit root null hypothesis. Results from the second-generation panel unit root tests were tabulated in Table 3. We tabulated all related test statistics and their probability values.

As given in Table 3, three out of four panel unit root tests—MP, Choi and CIPS — indicate that EF is stationary for both the high- and low-income economies. Likewise, results from the three panel unit root tests—BN, MP and Choi— signal that EF is stationary for the panel of the upper-middle income countries. However, only two panel unit root tests— MP and Choi— state evidence for the stationarity of EF in the lower-middle income economies. Panel-based unit root tests indicate that EF is stationary in both the panels of high- and low-income countries. Besides, there is also much evidence of stationarity of EF in the upper-middle income countries panel, particularly in the case of second-generation panel unit root tests. However, there is less evidence for the stationarity of EF in the low-income countries panel.

Panel unit root tests cannot determine the combination of I (0) and I (1) series in a panel setting given that they are joint tests of a unit root for all panel members. Also, failure to incorporate structural breaks into model cannot efficiently detect mean reversion in EF. Therefore, we applied the Panel KSS unit root test with a Fourier function in the framework of SPSM to identify how many and which countries in each country panel have stationary EF. Extending the model defined in Eq. (4) with a Fourier function allows us to approximate structural breaks as smooth and gradual processes. As there is no a priori knowledge concerning the shape of the breaks in the data, first a grid-search is performed to find the best frequency. To this aim, Eq. (6) is estimated for each integer k = 1–5 following the recommendations of Enders and Lee (2004), 2012).

Results from the Ucar and Omay (2009) test are provided in Tables 4–7, where UO statistic refers to the test statistic of the Ucar and Omay (2009) panel unit root test (i.e., Panel KSS test statistic); Min. KSS indicates the individual Kapetanios et al. (2003) unit root test statistic for the country that has the minimum KSS test statistic value; k is the number of frequency in the Fourier function and reflects the swing of smooth structural breaks in the per capita EF data; and Series shows the country which has stationary per capita EF and the minimum KSS test statistic.

For the high-income countries, the results of the SPSM based on the Panel KSS unit root test on EF are shown in Table 4. The SPSM provides a sequence of the panel KSS statistic with their bootstrap p-values on a reducing panel. The individual minimum KSS statistic and the stationary series are identified by this procedure each time. As we can see from Table 4, the null hypothesis of unit root in EF is rejected when the panel KSS unit root test is first applied to the whole panel, producing a value of -3.329 with a very small p-value of 0.000. Implementation of the SPSM shows that Sweden is stationary with a minimum KSS value of -5.682. Thus, Sweden is removed from the panel and the Panel KSS unit root test is applied again to the remaining set of countries. At this time, we obtain that the Panel KSS test still rejects the unit root null with a value of –3.248 (p-value of 0.000) and French Polynesia is found to be stationary with a minimum KSS value of –5.381. French Polynesia is then removed from the panel and the Panel KSS unit root test is implemented again to the remaining set of countries. The procedure continues until the Panel KSS test fails to reject the unit root null hypothesis at the 10% significance level. As seen in Table 4, the unit root null hypothesis cannot be rejected when the Panel KSS test is applied twenty-six times, yielding a value of −1.761 (with a p-value of 0.225). This study continues to perform the SPSM procedure until the last sequence to check the robustness of the results. The results from the Panel KSS test show that EF is non-stationary for only five countries; namely Chile, Singapore, Spain, United Kingdom and Poland. As sum, EF is stationary for the most high-income countries. Additionally, based on the Min. KSS test statistic values, we can state that in the 25 countries that have stationary EF, shocks to the per capita EF are temporary and do not have long-lasting effects. The same-above procedure was followed for the panel of upper-middle income countries and the results were provided in Table 5.

Similar to the panel of high-income countries, the null hypothesis is rejected when the Panel KSS test is first applied to the whole panel, producing a value of -2.349 (with a very small p-value of 0.000). SPSM confirmed the stationarity of Costa-Rica with a minimum KSS value of -4.837 and Costa-Rica is removed from the panel. After that the Panel KSS test is applied again to the remaining set of countries and the unit root null hypothesis is rejected with a value of –2.257 (p-value of 0.000). At this time, Argentina is found to be stationary with a minimum KSS value of –4.369. It is removed from the panel and the Panel KSS test is implemented again to the remaining set of countries. The procedure is continued until the Panel KSS unit root test fails to reject the unit root null hypothesis at the 10% significance level. As seen in Table 5, the null hypothesis cannot be rejected when the Panel KSS test is applied twelve-times, yielding a value of −1.611 (with a p-value of 0.115). However, the procedure continues to perform the SPSM procedure until the last sequence to check the robustness of the results.

Finally, among 28 upper-middle income countries, 11 countries (i.e. Costa Rica, Argentina, Dominica, Saint Lucia, Venezuela, Mexico, Ecuador, Bulgaria, South Africa, Paraguay, and Dominican Republic) are found to have stationary per capita EF. For the remaining 17 countries (i.e. Colombia, Lebanon, Guyana, Brazil, Cuba, Panama, Romania, Fiji, Albania, Peru, Mauritius, Tonga, Malaysia, Thailand, Turkey, China, and Algeria), EF appears to be nonstationary. As sum, EF includes unit root for over half of the upper- middle income countries. Additionally, based on the Min. KSS test statistic values, we obtained that in eleven countries, shocks to the per capita EF are transitory, whereas for the remaining seventeen countries that have nonstationary per capita EF, shocks to the per capita EF have long-lasting and permanent effects.

The same procedure and steps are followed for both the lower-middle income and low-income countries panels. Their results are shown in Tables 6 and 7. Results from the Table 6 indicate that unit root null hypothesis in EF cannot be rejected when the Panel KSS test is first applied to the lower-middle countries panel. Thus, the procedures are eased and concluded that EF has a unit root for all lower-middle income countries. This result also confirms the results of the first- and second-generation panel unit root tests achieved for the lower-middle income countries. Therefore, shocks to the per capita EF in all lower-middle

Table 3
Results from the second-generation panel unit root tests.

High-income countries					
Bai and Ng	$\hat{r}$	$Z_{\hat{e}}^{c}$	$P_{\hat{e}}^{c}$	MQ_c	MQ_f
	3.0	0.007	60.081	2.000	2.000
		(0.497)	(0.473)		
Moon and Perron	t_a^*	t_b^*	$\hat{\rho}^*_{pool}$	t_a^{*B}	t_b^{*B}
	-20.688[a]	-9.425[a]	0.872	-20.790	-9.520
	(0.000)	(0.000)		(0.000)	(0.000)
Choi	P_m	Z	L^*		
	16.283[a]	-10.049[a]	-11.567[a]		
	(0.000)	(0.000)	(0.000)		
Pesaran	CIPS	CIPS*	P^*		
	-2.370[b]	-2.370[b]	1		
	(0.010)	(0.010)			
Upper-middle income countries					
Bai and Ng	$\hat{r}$	$Z_{\hat{e}}^{c}$	$P_{\hat{e}}^{c}$	MQ_c	MQ_f
	3.0	1.483[c]	71.692[c]	1.000	3.000
		(0.069)	(0.077)		
Moon and Perron	t_a^*	t_b^*	$\hat{\rho}^*_{pool}$	t_a^{*B}	t_b^{*B}
	-17.303[a]	-9.211[a]	0.893	-17.275[a]	-9.285[a]
	(0.000)	(0.000)		(0.000)	(0.000)
Choi	P_m	Z	L^*		
	4.615[a]	-4.100[a]	-4.235[a]		
	(0.000)	(0.000)	(0.000)		
Pesaran	CIPS	CIPS*	P^*		
	-1.987	-1.987	1		
	(0.180)	(0.180)			
Lower-middle income countries					
Bai and Ng	$\hat{r}$	$Z_{\hat{e}}^{c}$	$P_{\hat{e}}^{c}$	MQ_c	MQ_f
	3.0	-2.003	36.426	2.000	2.000
		(0.977)	(0.988)		
Moon and Perron	t_a^*	t_b^*	$\hat{\rho}^*_{pool}$	t_a^{*B}	t_b^{*B}
	-7.161[a]	-4.548[a]	0.956	-7.114[a]	-4.563[a]
	(0.000)	(0.000)		(0.000)	(0.000)
Choi	P_m	Z	L^*		
	1.251 (0.105)	-1.359[c]	-1.361[c]		
		(0.087)	(0.087)		
Pesaran	CIPS	CIPS*	P^*		
	-1.193	-1.193	1		
	(0.990)	(0.990)			
Low-income countries					
Bai and Ng	$\hat{r}$	$Z_{\hat{e}}^{c}$	$P_{\hat{e}}^{c}$	MQ_c	MQ_f
	3.0	0.088	52.900	2.000	2.000
		(0.465)	(0.439)		
Moon and Perron	t_a^*	t_b^*	$\hat{\rho}^*_{pool}$	t_a^{*B}	t_b^{*B}
	-11.163[a]	-6.172[a]	0.927	-11.149[a]	-6.217[a]
	(0.000)	(0.000)		(0.000)	(0.000)
Choi	P_m	Z	L^*		
	8.217[a]	-4.794[a]	-5.772[a]		
	(0.000)	(0.000)	(0.000)		
Pesaran	CIPS	CIPS*	P^*		
	-2.090[c]	-2.090[c]	1		
	(0.085)	(0.085)			

Notes: The entry in parentheses are p-values. Constant term was included into model. In Bai and Ng (2004): $\hat{r}$ is the estimated common factors. $P_{\hat{e}}^{C}$ is a Fisher's type statistic, $Z_{\hat{e}}^{C}$ is a standardized Choi's type statistic. The entry in parentheses are p-values. The first and second estimated values of are derived from the filtered tests MQ_f and the corrected test, MQ_crespectively. In Moon and Perron (2004): t_a^* and $t_b^*$are the unit root test statistics based on de-factored panel data; $\widehat{P}^*_{pool}$ is the corrected pooled estimates of the auto-regressive parameter; t_a^{*B} and $t_b^{*B}$are computed with a Bartlett kernel function in spite of a Quadratic Spectral kernel function. In Choi (2002): P_m indicates a modified Fisher's inverse chi-square test, Z is an inverse normal test, and L^* is a modified logit test. In Pesaran (2007): CIPS denotes the mean of individual cross sectionally augmented ADF (CADF) statistics, while CIPS* implies the mean of truncated individual CADF statistics. The nearest integer of the mean of the individual lag lengths in ADF test is represented by P^*.

Table 4
Results from the Ucar and Omay (2009) unit root test with a Fourier function for the high-income countries.

Sequence	UO Statistic	Min. KSS (t-stat)	Fourier (k)	Series
1	−3.3294 (0.000)	−5.6822	1	Sweden
2	−3.2483 (0.000)	−5.3815	2	French Polynesia
3	−3.1721 (0.000)	−4.9257	3	Canada
4	−3.1072 (0.000)	−4.8802	2	New Zealand
5	−3.0390 (0.000)	−4.5483	1	Australia
6	−2.9786 (0.000)	−4.0499	1	Israel
7	−2.9340 (0.000)	−4.0207	1	Netherlands
8	−2.8867 (0.000)	−3.9956	1	Italy
9	−2.8363 (0.000)	−3.7601	2	France
10	−2.7923 (0.000)	−3.7586	3	Hungary
11	−2.7440 (0.000)	−3.6387	1	Greece
12	−2.6969 (0.000)	−3.6303	1	Portugal
13	−2.6451 (0.000)	−3.5961	1	Belgium
14	−2.5891 (0.000)	−3.5652	1	Japan
15	−2.5281 (0.000)	−3.4268	1	Ireland
16	−2.4682 (0.000)	−3.3272	1	Cyprus
17	−2.4068 (0.001)	−3.1520	2	Denmark
18	−2.3495 (0.001)	−3.0987	5	Germany
19	−2.2871 (0.002)	−3.0259	1	United States
20	−2.2199 (0.005)	−2.8384	2	Luxembourg
21	−2.1581 (0.009)	−2.7618	2	Switzerland
22	−2.0910 (0.018)	−2.7204	1	Barbados
23	−2.0123 (0.033)	−2.5401	5	Norway
24	−1.9369 (0.059)	−2.3999	1	Austria
25	−1.8597 (0.089)	−2.3489	4	South Korea
26	−1.7619 (0.225)	−2.0570	2	Chile
27	−1.6881 (0.205)	−2.0025	2	Singapore
28	−1.5834 (0.375)	−1.9243	3	Spain
29	−1.4129 (0.510)	−1.4324	3	United Kingdom
30	−1.3934 (0.592)	−1.3934	2	Poland

Notes: Constant is included into the model. Entries in parentheses stand for the p-value that is computed by means of bootstrap simulations using 5000 replications. The maximum lag is set to be 3. Fourier (k) is chosen by minimum sum square of residual for a Fourier function.

Table 5
Results for the Ucar and Omay (2009) test with a Fourier function for the upper-middle income countries.

Sequence	UO Statistic	Min. KSS (t-stat)	Fourier (k)	Series
1	−2.349 (0.000)	−4.8372	2	Costa Rica
2	−2.257 (0.000)	−4.3696	2	Argentina
3	−2.175 (0.000)	−4.0159	1	Dominica
4	−2.102 (0.000)	−3.8385	3	Saint Lucia
5	−2.030 (0.002)	−3.5952	1	Venezuela
6	−1.961 (0.006)	−3.1594	1	Mexico
7	−1.907 (0.017)	−3.1279	1	Ecuador
8	−1.849 (0.034)	−3.0294	3	Bulgaria
9	−1.790 (0.054)	−2.8812	1	South Africa
10	−1.733 (0.065)	−2.77	1	Paraguay
11	−1.675 (0.077)	−2.7619	1	Dominican Republic
12	−1.611 (0.115)	−2.7599	3	Colombia
13	−1.539 (0.138)	−2.7403	5	Lebanon
14	−1.459 (0.227)	−2.5319	1	Guyana
15	−1.383 (0.253)	−2.5308	1	Brazil
16	−1.294 (0.358)	−2.5024	4	Cuba
17	−1.194 (0.398)	−2.3873	4	Panama
18	−1.085 (0.478)	−2.173	1	Romania
19	−0.976 (0.513)	−1.9894	3	Fiji
20	−0.864 (0.623)	−1.5437	1	Albania
21	−0.779 (0.635)	−1.4327	1	Peru
22	−0.686 (0.644)	−1.2776	1	Mauritius
23	−0.587 (0.764)	−1.2335	1	Tonga
24	−0.458 (0.816)	−1.0496	1	Malaysia
25	−0.3106 0.826)	−0.5225	2	Thailand
26	−0.24 (0.702)	−0.3128	4	Turkey
27	−0.2036 (0.628)	−0.2301	5	China
28	−0.1771 (0.568)	−0.1771	1	Algeria

Notes: Constant is included in the model. Entries in parentheses stand for the p-value that is computed by means of bootstrap simulations using 5000 replications. The maximum lag is set to be 3. Fourier (k) is chosen by minimum sum square of residual for Fourier function.

income countries appear to be persistent and to have long-lasting effects. Concerning the panel of low-income countries, the results are tabulated in Table 7.

Referring to Table 7, the unit root null hypothesis in EF cannot be rejected when the panel KSS test is applied fifteen-times, yielding a value of −2.755 (with a p-value of 0.163). Based on these results, 14 out of 26 low-income countries, i.e. Gambia, Democratic Republic of Korea, Senegal, Niger, Haiti, Burkina Faso, Mozambique, Benin, Rwanda, Central African Republic, Mali, Malawi, Zimbabwe, and Togo, have stationary EF series. The remaining 12 low-income countries, namely Afghanistan, Guinea-Bissau, Nepal, Chad, Guinea, Somalia, Sierra Leone, Burundi, Tanzania, Madagascar, Democratic Republic of the Congo and Uganda have nonstationary EF series. Overall, for more than half of the low-income countries, EF appears to be stationary. Additionally, based on the Min. KSS test statistic values, we obtained that fourteen countries have stationary per capita EF series, indicating that shocks to the per capita EF in those fourteen countries are temporary, while they are persistent in the remaining twelve countries.

In a nutshell, the Panel KSS test results show that nearly all high-income countries, over the half of the low-income countries and less than half of the upper-middle income countries have stationary EF. However, lower-middle income countries have nonstationary EF series. We can compare our results only with those of Ulucak and Lin (2017) and Solarin and Bello (2018) as there are currently two studies in the literature. Ulucak and Lin (2017) confirmed the nonstationarity of EF in the USA while Solarin and Bello (2018) suggested that 96 out of 128 countries or 81% of the total sample are nonstationary. Economic rationale behind our results could be explained based on the development differences among countries. The result of stationarity for the high- and low-income countries panels imply that EF will return to its original symmetric path after being hit by a shock. Thus, governments of the high- and low-income countries should not adopt unnecessary targets when EF temporarily deviates from the trend path because environmental management policies designed to reduce EF have no long-lasting effects. High-income countries are developed and wealthy countries. They can easily adapt more efficient and eco-friendly technologies in their production processes. Besides, their inhabitants have high level of environmental awareness, resulting in less pressure on nature. The results for the upper-middle income countries are nearly similar to those for the high-income countries. EF appears to be stationary for the upper-middle income group, as well; however, there are fewer countries with stationary EF compared to the high- income countries. Concerning the low-income or undeveloped countries, they have abundant natural resources and more virgin land. In general, their inhabitants do not have much pressure on their habitats because they use environment to survive not for commercial purpose. Thus, they live in a friendly way in the nature; for instance, there is less construction; there is less manufacturing and, so on. Moreover, it is important to understand the influence of policies that will be implemented in the forthcoming years to address climate change (Ulucak & Lin, 2017). As such, the result of stationarity means that it is feasible to statistically forecast future movements in EF based only on its past behavior. Additionally, as a byproduct of our analyses, these results can be

Table 6
Results for the Ucar and Omay (2009) test with a Fourier function for the lower-middle income countries.

Sequence	UO Statistic	Min. KSS (t-stat)	Fourier (k)	Series
1	−1.631 (0.160)	−4.059	1	Philippines
2	−1.544 (0.293)	−3.474	4	Pakistan
3	−1.473 (0.398)	−3.096	3	Sudan
4	−1.4106 (0.492)	−2.909	1	Myanmar
5	−1.3506 (0.602)	−2.761	5	Guatemala
6	−1.2918 (0.661)	−2.757	1	El Salvador
7	−1.2281 (0.764)	−2.648	5	Congo
8	−1.1635 (0.832)	−2.514	1	Kenya
9	−1.0992 (0.877)	−2.442	1	Cameroon
10	−1.0321 (0.904)	−2.377	1	Nigeria
11	−0.9612 (0.930)	−2.205	4	Sri Lanka
12	−0.8921 (0.958)	−1.979	1	Syrian Arab Republic
13	−0.8282 (0.970)	−1.858	4	Vietnam
14	−0.7638 (0.981)	−1.732	1	Laos
15	−0.6992 (0.982)	−1.683	1	CÃ´te d'Ivoire
16	−0.6289 (0.987)	−1.551	3	Ghana
17	−0.5579 (0.985)	−1.372	1	Bhutan
18	−0.4901 (0.984)	−1.346	3	Angola
19	−0.4122 (0.981)	−1.323	4	Bolivia
20	−0.3211 (0.989)	−1.155	1	Tunisia
21	−0.2284 (0.994)	−0.884	5	Zambia
22	−0.1464 (0.997)	−0.697	3	Egypt
23	−0.0676 (0.996)	−0.688	1	Indonesia
24	0.0359 (0.994)	−0.631	2	Nicaragua
25	0.1694 (0.995)	−0.357	2	Jordan
26	0.3011 (0.991)	−0.180	2	Yemen
27	0.4616 (0.972)	−0.077	1	Sao Tome and Principe
28	0.7312 (0.977)	0.013	4	Morocco
29	1.4486 (0.972)	1.448	1	India

Notes: Constant is included in the model. Entries in parentheses stand for the p-value that is computed by means of bootstrap simulations using 5000 replications. The maximum lag is set to be 3. Fourier (k) is chosen by minimum sum square of residual for Fourier function.

Table 7
Results for the Ucar and Omay (2009) test with a Fourier function for the low income countries.

Sequence	UO Statistic	Min. KSS (t-stat)	Fourier (k)	Series
1	−3.2228	−6.5583 (0.000)	1	Gambia
2	−3.0894	−6.1852 (0.000)	1	Korea, Dem.
3	−2.9604	−6.0487 (0.000)	1	Senegal
4	−2.8261	−5.4961 (0.000)	1	Niger
5	−2.7048	−5.2831 (0.000)	1	Haiti
6	−2.582	−5.1424 (0.000)	3	Burkina Faso
7	−2.454	−5.0068 (0.000)	3	Mozambique
8	−2.3196	−4.3207 (0.000)	3	Benin
9	−2.2084	−4.1611 (0.001)	2	Rwanda
10	−2.0936	−4.0071 (0.004)	1	Central African Republic
11	−1.974	−3.6804 (0.011)	1	Mali
12	−1.8602	−3.2811 (0.025)	4	Malawi
13	−1.7587	−2.9979 (0.043)	1	Zimbabwe
14	−1.6634	−2.8441 (0.087)	1	Togo
15	−1.565	−2.7556 (0.163)	1	Afghanistan
16	−1.4568	−2.7258 (0.293)	1	Guinea-Bissau
17	−1.3298	−2.1832 (0.406)	1	Nepal
18	−1.235	−1.5944 (0.411)	1	Chad
19	−1.1901	−1.5693 (0.491)	1	Guinea
20	−1.1359	−1.5296 (0.510)	1	Somalia
21	−1.0703	−1.3788 (0.667)	1	Sierra Leone
22	−1.0086	−1.3676 (0.631)	4	Burundi
23	−0.9189	−1.2273 (0.516)	2	Tanzania
24	−0.8161	−1.1908 (0.636)	5	Madagascar
25	−0.6287	−1.0518 (0.73)	2	Congo, Dem
26	−0.2056	−0.2056 (0.820)	1	Uganda

Notes: Constant is included in the model. Entries in parentheses stand for the p-value that is computed by means of bootstrap simulations using 5000 replications. The maximum lag is set to be 3. Fourier (k) is chosen by minimum sum square of residual for Fourier function.

considered that common environmental policies that might be carried out by these countries will have a high chance of applicability (Ahmed et al., 2016; Burnett, 2016; Westerlund & Basher, 2008) since stationarity of a panel confirms the environmental convergence among countries as emphasized in the introduction section.

Regarding the middle-income countries, EF is stationary in nearly half of the upper-middle income countries. In contrast, EF appears to be nonstationary in the all lower-middle income countries. The result of nonstationarity implies that any shock to EF will have long lasting effects and the disruptions in EF will have long-term effects on the nature. Therefore, the governments of lower-middle income countries should design environmental policies to prevent the environmental degradation and to lessen the pressure of human being on the nature. In this case, environmental management policies designed to shrink EF will have long lasting effects for the lower-middle income countries. As such, they have not reached the threshold income level after which development starts to alleviate environmental damage and provides environmental protection.

5. Conclusion and policy implications

This study aims to analyze the stationarity of EF in a number of countries classified by their income levels: high-income countries, upper-middle income countries, lower-middle income countries and low-income countries. To this aim, the Panel KSS unit root test developed by Ucar and Omay (2009)–as a main testing procedure– is used over the years 1961 to 2013. Moreover, the Panel KSS unit root test along with the SPSM procedure is extended with a Fourier function for robustness check. The SPSM procedure allows us to classify countries into stationary and nonstationary classes. Besides, as a comparison purpose, some univariate unit root tests and a number of first- and second-generation panel unit root tests are used as well. Panel unit root tests reveal that EF is certainly stationary in the panels of high- and low-income countries, whereas it is nonstationary in the panel of lower-middle income economies. Regarding the panel of upper-middle income countries, there is much evidence of stationarity. Concerning the individual country results, the SPSM procedure shows that nearly all high-income countries and over the half of the low-income countries have stationary EF, whereas all lower-middle income countries have nonstationary EF. Finally, for a little less (nearly half of the) than half of the upper-middle income countries, EF was found as stationary.

Based on the aforementioned results, some important policy implications could be suggested for the governments of countries under scrutiny. First, stationarity results in most high-income, low-income and upper-middle income countries confirm that shocks to the EF are temporary. It means that EF will return to its original trend path or mean after being hit by a shock in the habitat, energy market or any economic sector. Therefore, governments should not adopt unnecessary targets when the EF temporarily deviates from the trend path because environmental conservation and management policies designed to reduce the EF have no long-lasting effects. In this respect, the internal dynamics of the high-income, low-income and upper-middle income countries are likely to provide some solutions to revert back EF to its original trend path. For instance, a positive shock that leads EF to increase or have an upward trend, will be likely compensated with the technological improvements that reduce the pressure of human activities on the environment. Likewise, low-income countries can compensate the rising environmental pressure with their rich natural resource endowments. Therefore, the excessive political interferences seem to be unnecessary in this case. However, concerning the lower-middle income countries, shocks to the per capita EF appear to have long-lasting effects because EF will not be able to revert back to its original trend path or mean after being hit by a natural or economic shock. Therefore, the governments of the lower-middle income countries should design environmental policies to lessen the environmental pressure resulted from the human activities. In this case, environmental conservation and management policies designed to shrink EF will become successful in the lower-middle income countries. Besides, another policy suggestion for the lower-middle income countries is to get out of the middle-income trap. In this respect, economic development and growth policies need to be redesigned to increase the per capita income level. As suggested in the Environmental Kuznets Curve (EKC) hypothesis, the lower-middle income countries will likely attach more importance to their environmental quality levels when they surpass a critical level of per capita income. As such, economic development appears to a crucial solution for the lower-middle income countries to alleviate the increasing human pressure on the nature.

Second, the time series properties of EF shed some lights on the forecasting of future movements in human pressure on the habitat. Furthermore, environmental sustainability depends on the forecasting of EF and forecasting is a basic tool for the environmental management policies. By making use of the past values of EF, policy-makers can make predictions on the future pressure of human being on nature. In this regard, for the high-, low- and upper-middle income countries with stationary EF series, the statistically reliable forecasting is possible for the future based on past values of EF. In this way, a successful forecasting about the future environmental pressure of a given population can facilitate the work of policymakers. For instance, if the forecasting signals that EF will go up in the near future, governments can take some precautions against this alarming threat via some specific population policies, technological policies, environmental management policies, and so on. However, concerning the lower-middle income countries, the statistically reliable forecasting is not possible for the future behavior of EF based on its past behavior. Thus, policymakers cannot use forecasting as a basic policy tool to fight against environmental degradation, and in that case, it would be necessary to look at other determinants of the EF to generate forecasts about it.

As sum, the results obtained clearly show that, in general, all countries, but in particular, the lower-middle income countries should lessen their high dependence on fossil fuels, such as oil, coal, natural gas, petroleum and etc. Thereby, carbon footprint, the most significant portion of EF, could be mitigated. In this scenario, renewable energy sources might provide a solution to lessen the carbon footprint. Also, governments should subsidize the usage of green or eco-friendly technologies in production process. Furthermore, governments should design strict environmental laws and apply sanctions if these laws are violated by producers and consumers. For instance, governments can demand fine from consumers when they pollute environment, destroy the forests, fish in seasonal fishing ban, overgraze the land, and so on. Likewise, producers should pay higher tax or fine when they do not install filters on factory chimneys or emit high level of greenhouse gasses into air and dump their production waste into the nature.

As a final closing note, analyzing the unit root process of EF is a new research area and needs further examination. Therefore, analysis should be extended for different countries and specific groups of countries using different unit root testing procedures. Besides, time series features of the sub-components of EF might be analyzed in the future studies, too.

Appendix A

Tables A1–A4

Table A1
Individual unit root tests results for the panel of high-income countries.

Countries	ADF	PP	KPSS	KSS	KRUSE
Australia	−5.091[a]	−5.091[a]	0.053	−3.142[c]	13.289[b]
Austria	−2.847	−2.799	0.106	−2.415	5.905
Barbados	−2.341	−2.180	0.177[b]	−2.557	11.065
Belgium	−2.666	−2.671	0.071	−2.737	7.713
Canada	−4.558[a]	−4.559[a]	0.156[b]	−3.593[b]	13.658[b]
Chile	−2.327	−2.229	0.138[c]	−2.082	4.794
Cyprus	0.118	0.073	0.181[b]	1.248	4.800
Denmark	−2.417	−2.417	0.210[b]	−1.018	2.877
France	−2.687	−2.687	0.139[c]	−2.442	6.057
French Polynesia	−2.623	−2.582	0.150[b]	−2.308	6.200
Germany	−2.492	−2.485	0.202[b]	−2.356	5.458
Greece	−0.508	−0.508	0.196[b]	−0.191	11.979[c]
Hungary	−2.965	−2.840	0.184[b]	−1.859	3.640
Ireland	−1.786	−1.616	0.174[b]	−0.886	5.722
Israel	−3.346[c]	−3.338[c]	0.065	−2.564	6.531
Italy	−1.824	−1.824	0.204[b]	−2.296	7.675
Japan	−2.675	−2.659	0.156[b]	−2.373	5.994
South Korea	−5.164[a]	−5.071[a]	0.249[a]	−7.750[a]	59.665[a]
Luxembourg	−3.236[c]	−3.393[c]	0.153[a]	−3.297[c]	20.536[a]
Netherlands	−2.874	−2.821	0.114	−2.360	5.479
New Zealand	−4.203[a]	−4.169[a]	0.078	−4.170[a]	17.901[a]
Norway	−2.866	−2.583	0.143[c]	−1.398	2.840
Poland	−1.957	−2.042	0.168[b]	−1.670	2.832
Portugal	−0.821	−0.800	0.108	−0.816	1.595
Singapore	−2.569	−2.422	0.191[b]	−2.921	8.386
Spain	−0.735	−1.013	0.114	−1.123	3.290
Sweden	−4.940[a]	−4.961[a]	0.100	−5.243[a]	34.063[a]
Switzerland	−3.243[c]	−3.278[c]	0.202[b]	−4.024[a]	15.886[b]
UK	−1.920	−2.258	0.102	−1.500	2.771
USA	−2.070	−2.095	0.129[c]	−1.933	4.926

Notes: The critical values are 0.216, 0.146 and 0.119 for the KPSS unit root test; -4.144, -3.498 and -3.178 for the ADF test and -4.144, -3.498 and -3.178 for the PP test at 1%, 5% and 10% significance levels, respectively. [a], [b] and [c] indicate rejection of the unit root null hypothesis at 1%, 5% and 10% significance levels, respectively. The critical values for the KSS unit root test are -3.93, -3.40 and -3.13 and the critical values for the Kruse test are 17.10, 12.82 and 11.10 at 1%, 5% and 10% significance levels, respectively.

Table A2
Individual unit root tests results for the panel of upper-middle income countries.

Countries	ADF	PP	KPSS	KSS	KRUSE
Albania	−1.285	−4.324[a]	0.154[b]	−0.289	0.181
Algeria	−2.137	−2.188	0.134[c]	−2.793	8.104
Argentina	−3.017	−3.002	0.107	−1.511	3.596
Brazil	−1.975	−2.082	0.168[b]	−1.965	3.872
Bulgaria	−2.889	−2.930	0.167[b]	−2.472	6.041
China	−0.995	−1.171	0.194[b]	−0.618	1.232
Colombia	−2.687	−2.692	0.122[c]	−2.174	7.604
Costa Rica	−3.647[b]	−3.598[b]	0.069	−3.843[b]	16.945[b]
Cuba	−2.015	−2.186	0.174[b]	−2.181	4.831
Dominica	−2.146	−1.954	0.162[b]	−1.769	3.151
Dominican Republic	−2.901	−3.012	0.070	−2.626	7.225
Ecuador	−2.323	−2.216	0.198[b]	−1.991	4.739
Fiji	−3.820[b]	−3.202[c]	0.137[c]	−2.823	7.834
Guyana	−1.078	−1.153	0.173[b]	−1.080	1.145
Lebanon	−1.361	−1.261	0.202[b]	−1.541	2.476
Malaysia	−3.055	−3.114	0.091	−3.093	9.444
Mauritius	−1.357	−2.528	0.185[b]	−1.466	3.475
Mexico	−1.977	−4.058[b]	0.113	−2.760	7.656
Panama	−2.285	−2.441	0.093	−2.879	8.849
Paraguay	−1.295	−1.477	0.178[b]	−2.253	4.977
Peru	−0.183	−0.321	0.240[a]	−1.720	3.412
Romania	−2.064	−2.062	0.195[b]	−2.042	4.678

(continued on next page)

Table A2 (*continued*)

Countries	ADF	PP	KPSS	KSS	KRUSE
South Africa	−2.501	−2.459	0.135[c]	−1.848	3.395
Saint Lucia	−1.576	−1.576	0.181[b]	−1.929	5.118
Thailand	−2.228	−2.270	0.104	−2.617	7.752
Tonga	−2.774	−2.668	0.156[b]	−2.474	6.758
Turkey	−5.790[a]	−5.792[a]	0.067	−1.218	2.239
Venezuela	−1.647	−2.129	0.091	−3.835[b]	15.078[b]

Notes: The critical values are 0.216, 0.146 and 0.119 for the KPSS unit root test; -4.152, -3.502 and -3.180 for the ADF test and -4.144, -3.498 and -3.178 for the PP test at 1%, 5% and 10% significance levels, respectively. [a], [b] and [c] indicate rejection of the unit root null hypothesis at 1%, 5% and 10% significance levels, respectively. The critical values for the KSS test are -3.93, -3.40 and -3.13 while they are 17.10, 12.82 and 11.10 for the Kruse test at 1%, 5% and 10% significance levels, respectively.

Table A3
Individual unit root tests results for the panel of lower-middle income countries.

Countries	ADF	PP	KPSS	KSS	KRUSE
Angola	−1.125	−1.304	0.141[c]	−1.759	3.096
Bhutan	−1.095	−1.385	0.176[b]	−0.891	0.811
Bolivia	−1.850	−1.759	0.106	−1.639	3.366
Cameroon	−0.413	−0.747	0.145[c]	−0.495	0.601
Congo	−2.954	−3.024	0.087	−2.044	5.350
CÃ´te d'Ivoire	−1.060	−1.898	0.133[c]	−1.083	1.570
Egypt	−3.043	−3.192[c]	0.115	−2.887	13.131[b]
El Salvador	−1.637	−1.576	0.199[b]	−1.341	2.535
Ghana	−1.192	−1.154	0.206[b]	−1.641	5.432
Guatemala	−2.126	−1.991	0.184[b]	−2.644	9.63
India	−1.413	−1.284	0.199[b]	−0.947	3.779
Indonesia	−3.304[c]	−3.522[b]	0.224[a]	−3.077	9.301
Jordan	−3.173	−3.173	0.098	−4.370[a]	19.086[a]
Kenya	−2.845	−2.878	0.161[b]	−2.948	9.202
Lao PDR	−0.308	−0.497	0.199[b]	−0.886	3.897
Morocco	−3.358[c]	−6.303[a]	0.203[b]	−3.048	9.802
Myanmar	−1.520	−1.478	0.206[b]	−2.513	6.504
Nicaragua	−4.121[b]	−4.047[b]	0.121[c]	−5.155[a]	28.741[a]
Nigeria	−2.494	−2.494	0.063	−2.360	5.612
Pakistan	−2.586	−2.570	0.076	−1.633	5.847
Philippines	−2.622	−2.487	0.089	−5.303[a]	27.777[a]
Sao Tome and Principe	−4.883[a]	−4.805[a]	0.063	−2.650	6.939
Sri Lanka	−1.727	−1.810	0.188[c]	−1.495	3.607
Sudan	−1.959	−2.001	0.087	−1.310	1.684
Syrian Arab Republic	−1.506	−3.180[c]	0.173[b]	−4.349[a]	21.337[a]
Tunisia	−4.114[b]	−4.159[c]	0.147[b]	−3.305[c]	10.776
Vietnam	−0.066	−0.332	0.232[a]	−2.276	5.071
Yemen	−2.804	−2.615	0.194[b]	−5.468[a]	30.637[a]
Zambia	−0.248	−0.245	0.187[b]	0.018	0.9113

Notes: The critical values for the KPSS unit root test are 0.216, 0.146; 0.119; -4.144, -3.498 and -3.178 for the ADF test and -4.144, -3.498 and -3.178 for the PP test at 1%, 5% and 10% significance levels, respectively. [a], [b] and [c] indicate rejection of the unit root null hypothesis at 1%, 5% and 10% significance levels, respectively. The critical values for the KSS test are -3.93, -3.40 and -3.13 and they are 17.10, 12.82 and 11.10 for the Kruse test at 1%, 5% and 10% significance levels, respectively.

Table A4
Individual unit root tests results for the panel of low-income countries.

Countries	ADF	PP	KPSS	KSS	KRUSE
Afghanistan	−0.459	−0.283	0.144[c]	−0.291	4.018
Benin	1.058	0.353	0.244[c]	−1.843	6.292
Burkina Faso	−4.719[a]	−4.672[a]	0.131[c]	−3.472[b]	12.277[c]
Burundi	−3.095	−3.021	0.166[b]	−0.639	2.106
Central African Republic	−1.191	−1.153	0.252[a]	−1.482	2.281
Chad	−2.085	−2.014	0.205[b]	−2.190	5.174
Congo, Dem.	−2.861	−2.914	0.111	−2.252	5.076
Gambia	−5.800[a]	−5.759[a]	0.040	−6.555[a]	42.545[a]
Guinea	−1.299	−1.987	0.148[b]	−3.360[c]	11.160[c]
Guinea-Bissau	−0.609	−0.442	0.252[a]	−2.938	8.549
Haiti	−3.815[b]	−3.921[b]	0.134[c]	−3.879	15.273
Madagascar	−3.081	−2.879	0.109	−2.653	6.948
Malawi	−1.501	−1.266	0.181[b]	−2.582	8.299

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Table A4 (*continued*)

Countries	ADF	PP	KPSS	KSS	KRUSE
Dem. Korea	−2.193	−2.226	0.154[b]	−2.918	10.076
Mali	−2.192	−2.192	0.199[b]	−2.593	6.749
Mozambique	−3.773[b]	−3.690[b]	0.114	−5.325[a]	28.711[a]
Nepal	−1.715	−1.590	0.224[a]	−2.380	8.125
Niger	−4.953[a]	−4.935[a]	0.113	−5.069[a]	27.928[a]
Rwanda	−2.945	−2.906	0.113	−3.207[c]	10.649
Senegal	−7.378[a]	−7.380[a]	0.126[c]	−7.456[a]	56.404[a]
Sierra Leone	−0.610	−0.610	0.211[b]	−0.995	1.324
Somalia	−1.999	−1.800	0.180[b]	−1.478	3.586
Tanzania	−3.720[b]	−3.720[b]	0.097	−3.475[b]	12.097[c]
Togo	−2.231	−2.268	0.196[b]	−1.997	5.064
Uganda	−1.607	−1.675	0.146[b]	−1.991	4.412
Zimbabwe	−4.489[a]	−4.189[a]	0.137[c]	−3.937[a]	15.201[b]

Notes: The critical values for the KPSS unit root test are 0.216, 0.146 and 0.119; -4.144, -3.498 and -3.178 for the ADF test and -4.144, -3.498 and -3.178 for the PP test at 1%, 5% and 10% significance levels, respectively. [a], [b] and [c] indicate rejection of the unit root null hypothesis at 1%, 5% and 10% significance levels, respectively. The critical values for the KSS test are -3.93, -3.40 and -3.13 and they are 17.10, 12.82 and 11.10 for the Kruse test at 1%, 5% and 10% significance levels, respectively.

References

Acar, S., & Aşıcı, A. A. (2016). Does income growth relocate ecological footprint? *Ecological Indicators, 61*, 707–714. https://doi.org/10.1016/j.ecolind.2015.10.022.

Acar, S., & Aşıcı, A. A. (2017). Nature and economic growth in Turkey: What does ecological footprint imply? *Middle East Development Journal, 9*(1), 101–115. https://doi.org/10.1080/17938120.2017.1288475.

Acaravcı, A., & Erdogan, S. (2016). The convergence behavior of CO2 emissions in seven regions under multiple structural breaks. *International Journal of Energy Economics and Policy, 6*(3), 575–580.

Ahmed, M., Khan, A. M., Bibi, S., & Zakaria, M. (2016). Convergence of per capita CO2 emissions across the globe: Insights via wavelet analysis. *Renewable and Sustainable Energy Reviews*. https://doi.org/10.1016/j.rser.2016.10.053.

Akbostancı, E., Turut-Asık, S., & Tunc, G. (2009). The relationship between income and environment in Turkey: Is there an environmental Kuznets curve? *Energy Policy, 37*, 861–867. https://doi.org/10.1016/j.enpol.2008.09.088.

Aldy, J. E. (2006). Per capita carbon dioxide emissions: Convergence or divergence? *Environmental and Resource Economics, 33*, 533–555.

Al-Mulali, U., Weng-Wai, C., Sheau-Ting, L., & Mohammed, A. H. (2015). Investigating the Environmental Kuznets Curve (EKC) hypothesis by utilizing the ecological footprint as an indicator of environmental degradation. *Ecological Indicators, 48*, 315–323.

Anoruo, E., & DiPietro, W. R. (2014). Convergence in per capita energy consumption among African countries: Evidence from sequential panel selection method. *International Journal of Energy Economics Policy, 4*(4), 568–577.

Apergis, N., & Ozturk, I. (2015). Testing Environmental Kuznets Curve hypothesis in Asian countries. *Ecological Indicators, 52*, 16–22.

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C. S., Jansson, B., Maler, K., Perrings, C., & Pimentel, D. (1995). Economic growth, carrying capacity, and the environment. *Ecological Economics, 15*, 91–95.

Aşıcı, A. A., & Acar, S. (2016). Does income growth relocate ecological footprint? *Ecological Indicators, 61*, 707–714.

Aslanidis, N. (2009). Environmental Kuznets curves for carbon emissions: A critical survey. In Nota Di Lavoro 75-2009. Fondazione Eni Enrico Mattei Woking Paper Series, Milano.

Bagliani, M., Bravo, G., & Dalmazzone, S. (2008). A consumption-based approach to Environmental Kuznets Curve using the ecological indicator. *Ecological Economics, 65*(3), 650–661.

Bai, J., & Ng, S. (2004). A PANIC attack on unit roots and cointegration. *Econometrica, 72*(4), 1127–1177.

World Bank (1995). *Monitoring environmental progress: A report on work in progress*Washington, D.C: Environmentally Sustainable Development, The World Bank.

Barassi, M. R., Cole, M. A., & Elliott, R. J. (2008). Stochastic divergence or convergence of per capita carbon dioxide emissions: Re-examining the evidence. *Environmental and Resource Economics, 40*(1), 121–137.

Barassi, M. R., Cole, M. A., & Elliott, R. J. (2011). The stochastic convergence of CO2 emissions: A long memory approach. *Environmental and Resource Economics, 49*(3), 367–385.

Barros, C. P., Gil-Alana, L. A., & De Gracia, F. P. (2016). Stationarity and long range dependence of carbon dioxide emissions: Evidence for disaggregated data. *Environmental and Resource Economics, 63*(1), 45–56.

Bartelmus, P. (2008). *Quantitative eco-nomics: How sustainable are our economies? Quantitative eco-nomics: How sustainable are our economies?*. Netherlands: Springer.

Becker, R., Enders, W., & Lee, J. (2006). A stationarity test in the presence of an unknown number of smooth breaks. *Journal of Time Series Analysis, 27*(3), 381–409.

Belbute, J. M., & Pereira, A. M. (2017). Do global CO 2 emissions from fossil-fuel consumption exhibit long memory? A fractional-integration analysis. *Applied Economics,* 1–16. https://doi.org/10.1080/00036846.2016.1273508.

Best, A., Blobel, D., Cavalieri, S., Giljum, S., Hammer, M., Lutter, S., ... Lewis, K. (2008). Potential of the ecological footprint for monitoring environmental impacts from natural resource use. *Sustainable Development.* http://ec.europa.eu/environment/natres/pdf/footprint.pdf.

Borucke, M., Moore, D., Cranston, G., Gracey, K., Iha, K., Larson, J., Lazarus, E., Moralesa, J. C., Wackernagela, M., & Alessandro Galli, A. (2013). Accounting for demand and supply of the biosphere's regenerative capacity: The National Footprint Accounts' underlying methodology and framework. *Ecological Indicators, 24*, 518–533.

Brännlund, R., Lundgren, T., & Söderholm, P. (2014). *CERE working paper: 10 convergence of carbon dioxide performance across Swedish industrial sectors. An environmental index approach.* Centre for Environmental and Resource Economics, Umeå University.

Brock, W. A., & Taylor, M. S. (2010). The green solow model. *Journal of Economic Growth, 15*(2), 127–153.

Brock, W. A., & Taylor, M. S. (2003). *The Kindergarten rule of sustainable growth (NBER No. Working Paper 9597).* Massachusetts.

Burnett, J. W. (2016). Club convergence and clustering of U.S. Energy-related CO2 emissions. *Resource and Energy Economics, 46*, 62–84. https://doi.org/10.1016/j.reseneeco.2016.09.001.

Camarero, M., Mendoza, Y., & Ordoñez, J. (2011). *Re-examining emissions. Is assessing convergence meaningless? Department of applied economics II universidad de valencia working papers, 1104*1–38.

Camarero, M., Picazo-Tadeo, A. J., & Tamarit, C. (2008). Is the environmental performance of industrialized countries converging? A 'SURE' approach to testing for convergence. *Ecological Economics, 66*, 653–661.

Caviglia-Harris, J. L., Chambers, D., & Kahn, J. R. (2009). Taking the U out of Kuznets: A comprehensive analysis of the EKC and environmental degradation. *Ecological Economics, 68*(4), 1149–1159.

Chambers, D., & Guo, J. T. (2009). Natural resources and economic growth: Some theory and evidence. *Annals of Economics and Finance, 10*(2), 367–389.

Chang, C. P., & Lee, C. C. (2008). Are per capita carbon dioxide emissions converging among industrialized countries? New time series evidence with structural breaks. *Environment Development Economics, 13*(4), 497–515.

Charfeddine, L. (2017). The impact of energy consumption and economic development on Ecological Footprint and CO 2 emissions: Evidence from a Markov switching equilibrium correction model. *Energy Economics, 65*, 355–374. https://doi.org/10.1016/j.eneco.2017.05.009.

Charfeddine, L., & Mrabet, Z. (2017). The impact of economic development and social-political factors on ecological footprint: A panel data analysis for 15 MENA countries. *Renewable and Sustainable Energy Reviews, 76*, 138–154. https://doi.org/10.1016/j.rser.2017.03.031.

Chen, Z., Barros, C. P., & Gil-Alana, L. A. (2016). The persistence of air pollution in four mega-cities of China. *Habitat International, 56*, 103–108.

Choi, I. (2001). Unit root tests for panel data. *Journal of International Money and Finance, 20*, 249–272.

Choi, I. (2002). *Combination unit root tests for cross-sectionally correlated panels, mimeo.* Hong Kong: Hong Kong University of Science and Technology.

Chortareas, G., & Kapetanios, G. (2009). Getting PPP right: Identifying mean-reverting real exchange rates in panels. *Journal of Banking and Finance, 33*, 390–404.

Christidou, M., Panagiotidis, T., & Sharma, A. (2013). On the stationarity of per capita carbon dioxide emissions over a century. *Economic Model, 33*, 918–925.

Criado, C. O., & Grether, J. M. (2011). Convergence in per capita CO2 emissions: A robust distributional approach. *Resource and Energy Economics, 33*(3), 637–665.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association, 74*(366a), 427–431.

Dietz, T., Rosa, E. A., & York, R. (2007). Driving the human ecological footprint. *Frontiers in Ecology and the Environment, 5*(1), 13–18.

Dogan, E. (2016). Are shocks to electricity consumption transitory or permanent? Subnational evidence from Turkey. *Utilities Policy, 41*, 77–84 https://doi.org/10.
EEA (2010). *The European environment State and outlook 2010: Synthesis.* Copenhagen. Retrieved fromhttp://www.ab.gov.tr/files/ardb/evt/1_avrupa_birligi/1_6_raporlar/1_3_diger/environment/eea_2010_the_european_environment_synthesis.pdf.
Enders, W., & Holt, M. T. (2012). Sharp breaks or smooth shifts? An investigation of the evolution of primary commodity prices. *American Journal of Agricultural Economics, 94*, 659–673.
Enders, W., & Lee, J. (2004). *Testing for a unit root with a nonlinear fourier function. Working paper.* Tuscaloosa, AL, USA: Department of Economics, Finance & Legal Studies, University of Alabama.
Enders, W., & Lee, J. (2012). A unit root test using a fourier series to approximate smooth breaks. *Oxford Bulletin of Economics and Statistics, 74*, 574–599. https://doi.org/10.1111/j.1468-0084.2011.00662.x.
Ezcurra, R. (2007). Is there cross-country convergence in carbon dioxide emissions? *Energy Policy, 35*, 1363–1372.
Fodha, M., & Zaghdoud, O. (2010). Economic growth and pollutant emissions in Tunisia: An empirical analysis of the environmental kuznets curve. *Energy Policy, 38*, 1150–1156. https://doi.org/10.1016/j.enpol.2009.11.002.
Galeotti, M., Lanza, A., & Pauli, F. (2006). Reassessing the Environmental Kuznets Curve for CO2 emissions: A robustness exercise. *Ecological Economics, 57*, 152–163. https://doi.org/10.1016/j.ecolecon.2005.03.031.
Gallant, A. R. (1981). On The bias in flexible functional forms and an essentially unbiased form: The flexible Fourier form. *Journal of Econometrics, 15*, 211–245.
Galli, A., Kitzes, J., Niccolucci, V., Wackernagel, M., Wada, Y., & Marchettini, N. (2012). Assessing the global environmental consequences of economic growth through the ecological footprint. A focus on China and India. *Ecol Indic, 17*, 99–107.
Gil-Alana, L. A., & Trani, T. (2018). Time trends and persistence in the global CO2 emissions across Europe. *Environmental and Resource Economics,* 1–16. https://doi.org/10.1007/s10640-018-0257-5.
Gil-Alana, L. A., Cunado, J., & Gupta, R. (2017). Persistence, mean-reversion and Non-linearities in CO2CO2Emissions: Evidence from the BRICS and G7 countries. *Environmental & Resource Economics, 67*(4), 869–883.
Grossman, G. M., & Krueger, A. B. (1991). *Environmental impacts of a North American Free trade agreement. National bureau of economic research working paper series, No. 3914*1–57. https://doi.org/10.3386/w3914 3914.
Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *Quarterly Journal of Economics. 110*(2), 353–377.
Guan, X., Li, Z., & Wang, G. (2008). Co-integration analysis and an error correction model for ecological footprint and economy growth in China. *Resources Science, 30*(2), 261–266 (in Chinese).
Hasanov, M., & Telatar, E. (2011). A re-examination of stationarity of energy consumption: Evidence from new unit root tests. *Energy Policy, 39*(12), 7726–7738. https://doi.org/10.1016/j.enpol.2011.09.017.
Herrerias, M. J. (2013). The environmental convergence hypothesis: Carbon dioxide emissions according to the source of energy. *Energy Policy, 61*, 1140–1150. https://doi.org/10.1016/j.enpol.2013.06.120.
Hervieux, M. S., & Darné, O. (2015). Environmental kuznets curve and ecological footprint: A time series analysis. *Economics Bulletin, 35*(1), 814–826.
Im, K. S., Pesaran, H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics, 115*, 53–74.
Islam, N. (2003). What have we learnt from the convergence debate? *Journal of Economic Surveys, 17*(3), 309–362. https://doi.org/10.1111/1467-6419.00197.
Isman, M., Archambault, M., Charles, N. K., Lin, D., Iha, K., & Ouellet-Plamondon, C. (2017). Ecological footprint assessment for targeting climate change mitigation in cities: A case study of 15 Canadian cities according to census metropolitan areas (CMA). *Journal of Cleaner Production*. https://doi.org/10.1016/J.JCLEPRO.2017.10.189.
Jaunky, V. (2011). The CO2 emissions-income nexus: Evidence from rich countries. *Energy Policy, 39*, 1228–1240. https://doi.org/10.1016/j.enpol.2010.11.050.
Jobert, T., Karanfil, F., & Tykhonenko, A. (2010). Convergence of per capita carbon dioxide emissions in the EU: Legend or reality? *Energy Economic, 32*, 1364–1373.
Jordá, V., & Remuzgo, L. (2013). *Testing global convergence in per capita CO2 emissions: A semiparametric approach.* http://www.reunionesdeestudiosregionales.org/Oviedo2013/ htdocs/pdf/p697.pdf. [Access on 19.07.16].
Jorgenson, A. K. (2003). Consumption and environmental degradation: A cross-national analysis of the ecological footprint. *Social Problems, 50*, 374–394.
Jorgenson, A. K., & Burns, T. J. (2007). The political-economic causes of change in the ecological footprints of nations, 1991-2001. *Social Science Research, 36*, 834–853.
Jorgenson, A. K., & Rice, J. (2005). Structural dynamics of international trade and material consumption: A cross-national study of the ecological footprints of less developed countries. *Journal of World-Systems Research, 11*, 57–77.
Kapetanios, G., Shin, Y., & Snell, A. (2003). Testing for a unit root in the nonlinear STAR framework. *Journal of Econometrics, 112*, 359–379.
Kasman, A., & Duman, Y. S. (2015). CO2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: A panel data analysis. *Economic Modelling, 44*, 97–103.
Kitzes, J., & Wackernagel, M. (2009). Answers to common questions in ecological footprint accounting. *Ecological Indicators, 9*(4), 812–817.
Kruse, R. (2011). A new unit root test against ESTAR based on a class of modified statistics. *Statistical Papers, 52*(1), 71–85.
Kwiatkowski, D., Phillips, P., Schmidt, P., & Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root? *Journal of Econometrics, 54*, 159–178.
Lanne, M., & Liski, M. (2003). Trends and breaks in per-capita carbon dioxide emissions. *IAEE The Energy Journal, 25*(4), 1870–2028.
Lee, C. C., & Chang, C. P. (2009). Stochastic convergence of per capita carbon dioxide emissions and multiple structural breaks in OECD countries. *Economic Modelling, 26*(6), 1375–1381.
Lee, C. C., & Chang, C. P. (2008). New evidence on the convergence of per capita carbon dioxide emissions from panel seemingly unrelated regressions augmented dickey-fuller tests. *Energy, 33*(9), 1468–1475.
Lee, C. C., & Lee, J. D. (2009). Income and CO2 emissions: Evidence from panel unit root and cointegration tests. *Energy Policy, 37*(2), 413–423. https://doi.org/10.1016/j.enpol.2008.09.053.
Lee, C. C., Chang, C. P., & Chen, P. F. (2008). Do CO2 emission levels converge among 21 OECD countries? New evidence from unit root structural break tests. *Applied Economics Letters, 15*(7), 551–556.
Levin, A., Lin, C. F., & Chu, C. S. (2002). Unit root in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics, 108*, 1–24.
Leybourne, S., Newbold, P., & Vougas, D. (1998). Unit roots and smooth transitions. *Time Series Analysis, 19*, 83–97.
Li, X., & Lin, B. (2013). Global convergence in per capita CO2 emissions. *Renewable & Sustainable Energy Reviews, 24*, 357–363.
Li, X., Tang, D. P., & Chang, T. (2014). CO2 emissions converge in the 50 US states—Sequential panel selection method. *Economic Modelling, 40*, 320–333.
List, J. A. (1999). Have air pollutant emissions converged among U.S. Regions? Evidence from unit root tests. *Southern Economic Journal, 66*(1), 144–155.
Liu, W. C. (2013). The study on the stationarity of energy consumption in US States: Considering structural breaks, nonlinearity, and Cross-sectional dependency, World Academy of Science. *International journal of mathematical and computational sciences, 7*(8), 796–815.
Lu, Y., & Chen, B. (2017). Urban ecological footprint prediction based on the Markov chain. *Journal of Cleaner Production, 163*, 146–153. https://doi.org/10.1016/J.JCLEPRO.2016.03.034.
Maddala, G. S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics, 61*, 631–652.
Magazzino, C. (2014). The relationship between CO2 emissions, energy consumption and economic growth in Italy. *International Journal of Sustainable Energy*. https://doi.org/10.1080/14786451.2014.953160.
McDonald, P., & Patterson, M. (2004). Ecological footprints and interdependencies of New Zealand regions. *Ecological Economics, 50*, 49–67.
Mishra, V., Sharma, S., & Smyth, R. (2009). Are fluctuations in energy consumption per capita transitory? Evidence from a panel of pacific Island countries. *Energy Policy, 37*(6), 2318–2326.
Moon, R., & Perron, B. (2004). Testing for a unit root in panels with dynamic factors. *Journal of Econometrics, 122*, 81–126.
Mostafa, M. M. (2010). Clustering the ecological footprint of nations using kohonen's self-organizing maps. *Expert Systems with Applications, 37*, 2747–2755.
Mrabet, Z., & Alsamara, M. (2017). Testing the kuznets curve hypothesis for Qatar: A comparison between carbon dioxide and ecological footprint. *Renewable and Sustainable Energy Reviews, 70*, 1366–1375. https://doi.org/10.1016/j.rser.2016.12.039.
Nguyen-Van, P. (2005). Distribution dynamics of CO2 emissions. *Environmental and Resource Economics, 32*, 495–550.
O'Connell, P. G. J. (1998). The overvaluation of purchasing power parity. *Journal of International Economics, 44*, 1–20.
Ozturk, I., Al-Mulali, U., & Sboori, B. (2016). Investing The Environmental Kuznets Curve Hypothesis: The role of tourism and ecological footprint. *Environmental Science and Pollution Research, 23*, 1916–1928.
Panopoulou, E., & Pantelidis, T. (2007). *Club convergence in carbon dioxide emissions. The Institute for International integration studies discussion paper series iiisdp235, IIIS.E.*.
Panopoulou, E., & Pantelidis, T. (2009). Club convergence in carbon dioxide emissions. *Environmental And Resource Economics, 44*(1), 47–70.
Perron, P. (1989). The great crash, the oil price shock, and the unit root hypothesis. *Econometrica, 57*, 1361–1401.
Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics, 22*, 265–312.
Phillips, P. C. B., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika, 75*(2), 335–346.
Phillips, P. C. B., & Sul, D. (2007). Transition modeling and econometric convergence tests. *Econometrica, 75*(6), 1771–1855. https://doi.org/10.1111/j.1468-0262.2007.00811.x Blackwell Publishing Ltd.
Presno, M. J., Landajo, M., & Fernández González, P. (2015). Stochastic convergence in per capita CO2 emissions. An approach from nonlinear stationarity analysis. *Energy Economics*. https://doi.org/10.1016/j.eneco.2015.10.001.
Prodan, R. (2008). Potential pitfalls in determining multiple structural changes with an application to purchasing power parity. *Journal of Business and Economic Statistics, 26*(1), 50–65.
Rashid, A., Irum, A., Ali Malik, I., Ashraf, A., Rongqiong, L., Liu, G., ... Yousaf, B. (2018). Ecological footprint of Rawalpindi; Pakistan's first footprint analysis from urbanization perspective. *Journal of Cleaner Production, 170*, 362–368.
Rees, W. E. (1992). Ecological footprints and appropriated carrying capacity: What urban economics leaves out. *Environment and Urbanization, 4*(2), 121–130.
Richmond, A., & Kaufmann, R. (2006). Is there a turning point in the relationship between income and energy use and/or carbon emissions? *Ecological Economics, 56*, 176–189. https://doi.org/10.1016/j.ecolecon.2005.01.011.
Robalino-López, A., García-Ramos, J. E., Golpe, A. A., & Mena-Nieto, A. (2016). CO2 emissions convergence among 10 South American countries. A study of Kaya components (1980–2010). *Carbon Management, 1–12*.
Romero-Ávila, D. (2008). Convergence in carbon dioxide emissions among industrialised countries revisited. *Energy Economics, 30*(5), 2265–2282. https://doi.org/10.1016/j.

eneco.2007.06.003.
Rothman, D. S. (1998). Environmental Kuznets curves—Real progress or passing the buck?: A case for consumption-based approaches. *Ecological Economics, 25*(2), 177–194.
Shahbaz, M., Solarin, S. A., Sbia, R., & Bibi, S. (2015). Does energy intensity contribute to CO2 emissions? A trivariate analysis in selected African countries. *Ecological Indicators, 50*, 215–224.
Smyth, R., & Narayan, P. K. (2015). Applied econometrics and implications for energy economics research. *Energy Economics, 50*, 351–358. https://doi.org/10.1016/j.eneco.2014.07.023.
Solarin, S. A. (2014). Convergence of CO2 emission levels: Evidence from African countries. *Research Journal of Economics, 19*(1), 65–92.
Solarin, S. A., & Bello, M. O. (2018). Persistence of policy shocks to an environmental degradation index: The case of ecological footprint in 128 developed and developing countries. *Ecological Indicators, 89*, 35–44. https://doi.org/10.1016/J.ECOLIND.2018.01.064.
Stern, D. I. (2014). *The environmental Kuznets curve: A primer (CCEP working paper 1404)*.
Strazicich, M. C., & List, J. A. (2003). Are CO2 emission levels converging among industrial countries? *Environmental and Resource Economics, 24*, 263–271.
Sun, J., Su, C. W., & Shao, G. L. (2016). Is carbon dioxide emission convergence in the ten largest economies? *International Journal of Green Energy, 13*(5), 454–461.
Tang, C. F., & Tan, B. W. (2015). The impact of energy consumption, income and foreign direct investment on carbon dioxide emissions in Vietnam. *Energy, 79*, 447–454.
Tiwari, A. K., Kyophilavong, P., & Albulescu, C. T. (2016). Testing the stationarity of CO2 emissions series in Sub-Saharan African countries by incorporating nonlinearity and smooth breaks. *Research in International Business and Finance, 37*, 527–540. https://doi.org/10.1016/j.ribaf.2016.01.005.
Ucar, N., & Omay, T. (2009). Testing for unit root in nonlinear heterogeneous panels. *Economics Letters, 104*, 5–8.
Uddin, G. A., Salahuddin, M., Alam, K., & Gow, J. (2017). Ecological footprint and real income: Panel data evidence from the 27 highest emitting countries. *Ecological Indicators, 77*, 166–175. https://doi.org/10.1016/J.ECOLIND.2017.01.003.
Ulucak, R., & Apergis, N. (2018). Does convergence really matter for the environment? An application based on club convergence and on the ecological footprint concept for the EU countries. *Environmental Science and Policy,* 80. https://doi.org/10.1016/j.envsci.2017.11.002.
Ulucak, R., & Bilgili, F. (2018). A reinvestigation of EKC model by ecological footprint measurement for high, middle and low income countries. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2018.03.191.
Ulucak, R., & Lin, D. (2017). Persistence of policy shocks to Ecological Footprint of the USA. *Ecological Indicators, 80*, 337–343. https://doi.org/10.1016/j.ecolind.2017.05.020.
UNDP (2014). *human development report 2014: Sustaining human progress, reducing vulnerabilities and building resilience*New York . Retrieved from http://hdr.undp.org/sites/default/files/hdr14-report-en-1.pdf.
United Nations (2015). *Resolution adopted by The General assembly on 25 September 2015: Transforming our world: The 2030 agenda for sustainable development.* Retrieved fromhttp://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1andLang=E.
Vackar, D. (2012). Ecological Footprint, environmental performance and biodiversity: A cross-national comparison. *Ecological Indicators, 16*, 40–46. https://doi.org/10.1016/j.ecolind.2011.08.008.
Wackernagel, M. (1994). *Ecological footprint and appropriated carryinng capacity: A toll for planning toward sustainability*The University of British Colombia PhD Thesis.
Wackernagel, M., & Rees, W. (1996). *Our Ecological Footprint: reducing human impact on the Earth.* Philadelphia, PA: New Society Publishers ISBN: 0-86571-312-X.
Wang, S. S., Zhou, D. Q., Zhou, P., & Wang, Q. W. (2011). CO2 emissions, energy consumption and economic growth in China: A panel data analyses. *Energy Policy, 39*(9), 4870–4875.
Wang, Y., Kang, L., Wu, X., & Xiao, Y. (2013). Estimating the environmental Kuznets curve for ecological footprint at the global level: A spatial econometric approach. *Ecol. Indicators, 34*, 15–21.
Wang, Z., Yang, L., Yin, J., & Zhang, B. (2017). Assessment and prediction of environmental sustainability in China based on a modified ecological footprint model. *Resources, Conservation and Recycling.* https://doi.org/10.1016/J.RESCONREC.2017.05.003.
Westerlund, J., & Basher, S. A. (2008). Testing for convergence in carbon dioxide emissions using a century of panel data. *Environmental and Resource Economics, 40*, 109–120.
Yamazaki, S., Tian, J., & Doko Tchatoka, F. (2014). Are per capita CO2 emissions increasing among OECD countries? A test of trends and breaks. *Applied Economics Letters, 21*(8), 569–572 2014.
Yavuz, N. C., & Yilanci, V. (2013). Convergence in per capita carbon dioxide emissions among G7 countries: A TAR panel unit root approach. *Environmental And Resource Economics, 54*(2), 283–291.
Yiqing, H., Ting, C., & Yun, W. (2012). Ecological Footprint and endogenous economic growth in the poyang lake area in China based on empirical analysis of panel data model. *Journal of Resources and Ecology, 3*(4), 367–372.
York, R., Rosa, E. A., & Dietz, T. (2004). The ecological footprints intensity of national economics. *Journal of Industrial Ecology, 8*(4), 139–154.
York, R., Rosa, E. A., & Dietz, T. (2003). Footprints on The earth: The environmental consequences of medernity. *American Sociological Review, 68*(2), 279–300.
York, R., Rosa, E. A., & Dietz, T. (2009). A tale of contrasting trends: Three measures of the ecological footprint in China, India, Japan and the United States. *American Sociological Review, 15*(2), 134–146.
Zhang, Y. J., & Da, Y. B. (2015). The decomposition of energy-related carbon emission and its decoupling with economic growh in China. *Renewable & Sustainable Energy Reviews, 4*, 1255–1266.
Zhang, L. F., Jia, W. P., & Liu, Y. C. (2010). Relation between the ecological footprint and the economic growth of hunan Bohai Sea economic region: An empirical analysis based on the panel data model. *Journal of Arid Land Resources and Environment, 24*(10), 1–7 (in Chinese).
Zhang, L., Dzakpasu, M., Chen, R., & Wang, X. C. (2017). Validity and utility of ecological footprint accounting: A state-of-the-art review. *Sustainable Cities and Society, 32*, 411–416. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S2210670716303602.
Zhao, X., Burnett, J., & Lacombe, D. J. (2014). *Province-level convergence of China CO2 emission intensity.* [Accessed on 15.01.15] http://ageconsearch.umn.edu/bitstream/169403/2/Zhao_AAEA_2014.pdf.