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Ecological footprint, tourism development, and country risk: International evidence

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A B S T R A C T

This research empirically explores the economic-, tourism-, and country risk ratings-induced Environmental Kuznets Curve (EKC) hypothesis by employing ecological footprints (EFs) as indicators of international environmental degradation. To account for distributional heterogeneities across countries as well as possible asymmetric relationships among variables, we apply a quantile regression approach by using panel data from 123 countries spanning 1992–2016. Our findings partially support that income, tourism, and country risk EKCs (i.e., inverted U-shape relation) exist in grazing land and forest land, signifying that these 2 types of land are sacrificed (increased) and then shift toward enhancing more environmental protection lifestyles as GDP, tourism revenues, and country risk ratings further rise. Conversely, U-shape relations generally exist in carbon-absorption land, cropland, and fishing ground, implying that growths of tourism, GDP, and country risk ratings have shifted from enhancing more environmentally protective policies to encouraging EF-consuming lifestyles for these EF components. In addition, we uncover that income development is largely responsible for increases in EF, while tourism generally and salient decreases forest land and grazing land. We also confirm the income EKC hypothesis in European countries. Tourism increases (reduces) fishing ground at lower (higher) fishing quantiles, suggesting the asymmetric impacts of tourism across different quantiles. The political risk rating shows a mostly positive impact on EF than those of economic and financial risk ratings, denoting the important impact of a country's political rating on environment degradation. Overall, the findings herein advocate the need for analysis that considers heterogeneities across countries, different EF quantiles, and different EF components in the tourism-, economic-, and country risk-induced EKC estimations.

1. Introduction

Utilizing the quantile regression (QR), this research examines whether non-linear and asymmetric impacts of economic development, tourism development, and country risk ratings on ecological footprint (EF hereafter) exist in a panel of 123 countries. Additionally, we explore whether the correlations among inverted U-shape tourism development, country risk rating, and economic development Environmental Kuznets Curve (EKC) hypotheses are supported across different EF quantiles and components. Our research flowchart appears in Figure A1.

Given the rising adversity in climate change and environmental degradation, concerns about the determinants of environmental quality are gaining growing attention in scholarly research as well as in the public policy arena. The term Kuznets curve comes from Kuznets (1955), who was a pioneer in estimating the association between income inequality and per capita income, concluding that income inequality increases along with growth in per capita income, however, continued economic development expressively reduces income inequality after reaching a certain level of income per capita - i.e., the threshold level. Extending the EKC hypothesis to environment issues, Grossman and Krueger (1991) are trailblazers at probing the associations between economic development and numerous environmental pollution indicators, finding an inverted U-shape association between per capita real income and environmental pollution and revealing that as economic development rises, CO_2 emissions first increase and then fall after reaching a

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certain turning point. Panayotou (1993) gives this inverted U-shape relationship with economic development the acronym EKC, because it is similar to Kuznets' (1955) curve. EKC is essentially a hypothetical association between several environmental pollutants and per capita income and shows diverse behaviors with dissimilar phases of economic development. In the early phases of economic development, environmental pollutants rise considerably, and it is expected after a threshold level of income per capita that emissions consequently decay and thus appear to improve environmental quality (Dinda, 2004; Chen and Lee, 2020).

The EKC hypothesis has also inspired noteworthy debate within academic and policy research, such as Lantz and Feng (2006) who find that previous studies may have misspecified the application of a linear relation between CO_2 emissions and GDP variables. Caviglia-Harris et al. (2009) study the validity of the EKC hypothesis with respect to ecological footprint across countries, present very weak support for the relation between the EF subcomponent and economic development, and conclude that economic development alone is not necessary for long-run sustainable development. However, the EF subcomponents in Caviglia-Harris et al. (2009) are different from the current EF subcomponents. Wang et al. (2013) explore the EKC hypothesis for the total EF score, employing cross-sectional data of 150 countries, but they do not show any evidence to support the hypothesis. Using CO2 emissions as a dependent variable, Chandran and Tang (2013) do not offer any supporting evidence for the EKC hypothesis in five ASEAN countries. Al-Mulali et al. (2015) indicate that EKC does support EF and GDP growth in upper middle- and high-income countries. Using total scores of EF, Ulucak and Bilgili (2018) confirm the EKC hypothesis by low-income, middle-income, and high-income group nations. Hassan et al. (2019) show the presence of the EKC hypothesis between GDP and EF. Destek and Sinha (2020) present a U-shape relationship between economic development and the total scores of ecological footprint. Therefore, regarding the issue of economic development induced EKC in EF, scant studies address the EKC hypothesis with different subcomponents of EF as well as different quantiles of EF subcomponents.

Tourism has long been recognized as a dominant tool for country development, spurring economic development, increasing foreign exchange, and raising local employment (Brau et al., 2007; Lee and Chang, 2008). According to the World Travel and Tourism Council (WTTC) (2019), one of the world's largest economic sectors is tourism, which in 2018 contributed US$8.8 trillion to the global economy, created 319 million jobs, and increased global GDP by 10.4%, or 10% of total employment. Tourism, the second faster-growing sector in 2018 only marginally behind manufacturing, has had a notable influence on the world economy (WTTC, 2019).[1] However, as the tourism sector flourishes, its related activities have also affected environment quality, such as traffic congestion, over-exploitation of natural resources, and issues generated by inappropriate tourist manners (Chen and Hsieh, 2011). Additionally, the development of the tourism sector requires massive investments in infrastructure such as roads, airports, and diverse tourism services (shops, resorts, restaurants, and hotels). Therefore, it is not surprising that tourism can induce a big burden on the environment (Ozturk et al., 2016). Subsequently, quick growth in tourism might raise major difficulties in terms of environment sustainability (Ozturk et al., 2016). Moreover, the promotion of tourism development without identifying its influence on biological diversity raises a big question mark for sustainable tourism (Milder et al., 2016). Those factors swaying environmental degradation are mostly inconclusive, and most existing studies often have not considered unobserved distributional heterogeneity across low and high environmental-degraded countries.

The association between tourism development and EKC has gained momentum as a research topic in the first decade of the new millennium, as evidenced by the large number of scholarly studies and policy implications for environmental protection in the sustained tourism policy literature. For example, Lee et al. (2010) show that inverted U-shape EKC relationships exist in Americas and Europe, but not in Africa and Asia and Oceania. De Vita et al. (2015) note that inbound tourism growth at the early level disturbs environmental quality, while at the exponential level tourism growth substantially decays, thus supporting an inverted U-shape tourism EKC hypothesis. Dogan et al. (2016) investigate real GDP and tourism EKC, but are unable to offer findings that support the EKC hypothesis. Ozturk et al. (2016) show that the tourism-induced EKC hypothesis more likely exists in upper middle- and high-income nations than in other income-level nations. Overall, past studies have not reached a consensus regarding tourism-induced EKC on EF, particularly different EF subcomponents.

Most studies proxy environmental quality by utilizing CO_2 emissions within the EKC framework (Yasin et al., 2019), but CO_2 emissions are a feeble mark for environmental quality, as they only help estimate air contamination, and so CO_2-based implications may be misleading (Ulucak and Lin, 2017). EF denotes the total area of ecologically productive land and water ecosystems (built-up area, carbon land, cropland, fishing area, forests, and grazing land) required to supply all the resources employed and to reabsorb all the emissions produced, wherever on earth that land and water may be located (Global Footprint Network (GFN) 2019). EF is very prevalent as an environmental performance criterion for countries, since it is a measurable, comprehensive, and easily understandable indicator (Ulucak and Lin, 2017). In addition, EF is a composite indicator of humanity's demand for natural resources, offers convenient insights about the environment, and is an imperative indicator for empirical analysis in explaining the associations between global environmental degradation, local environment pressure, and economic activities (Ulucak and Lin, 2017). Therefore, EF can be a comprehensive indicator of environmental degradation as it includes all three types of pollution (air, water, and soil) (Bello et al., 2018). Furthermore, scholars use EF as a proxy for environmental destruction to overcome the weakness of the majority of past studies that have employed CO_2 emissions to capture environmental damage (e.g. Yasin et al., 2019). Furthermore, Aydin et al. (2019) indicate that among the EF subcomponents, only fishing ground footprints confirm the income-induced EKC hypothesis. Aşıcı and Acar (2018) reveal that no EKC relationship is found between income and non-carbon footprints. These studies suggest that different EF subcomponents own diverse features and might have different determinates.

Several academics hold that the influence of economic development on environmental pollution is linked to political institutions. For example, Dasgupta and Mäler (1995) present that a country with strong environment governance is likely to pollute less than a country with bad environment governance. Romuald (2011) claims that many environmental issues could be illuminated through bad government policies or lack thereof and institutional failure. Wen et al. (2016) show that an environmental protection policy closely interacts with the national background of a certain country (i.e. its political and institutional environments), especially with powerful political parties. Dasgupta and De Cian (2018) also show that the effects of environmental intervention depend on the political environment leading to policy choice. Moreover, a growing body of research has introduced related

[1] Data source: Travel & tourism economic impact 2019 world from World Travel & Tourism Council. https://www.wttc.org/-/media/files/reports/economic-impact-research/regions-2019/world2019.pdf.

variables into the model, such as civil liberties (Carlsson and Lundström, 2001), democracy (You et al., 2015), corruption (Arminen and Menegaki, 2019), and institutional quality (Zakaria and Bibi, 2019), among others. Notably, country risk ratings can be considered as the integrated reflection of economic strength, political stability, as well as the capacity and willingness to offer services for financial obligations (Hoti and McAleer, 2002). However, remarkably little is known regarding the impact of country risk rating (i.e. economic, financial, and political risks) on the different components of EF. Thus, to the authors' knowledge, by employing country risk ratings this paper beneficially supplements the literature on the country risk rating EKC hypothesis.

Based on the above discussions, the contributions of this study are as follows. First, it is an original in the literature by exploring country risk ratings (CRs) in the EKC hypothesis as determinants of EF components. The reason why we use CR is that the literature mentions the importance of environmental governance (Dasgupta and Mäler, 1995), political freedom (Torras and Boyce, 1998), government and institutional factors (Romuald, 2011), political and institutional environments (Dasgupta and De Cian, 2018), civil liberties (Joshi and Beck, 2018), democracy (Usman et al., 2019), corruption (Arminen and Menegaki, 2019), and institutional quality (Zakaria and Bibi, 2019), which are elements in country risk ratings and which can impact the environment. Multifaceted CRs (i.e., economic, financial, and political risk ratings) provide more inclusive indices than any single indicator, and the measures often compound the problem by lumping key variables into a single index (Oetzel et al., 2001). Additionally, country risk ratings might become an opportunity to benefit environmental quality. Our findings thus pinpoint the possible country risk determinants for environment degradation.

Second, unlike a linear assumption, this paper explores possible non-linear or asymmetric relationships among EF, CR, international tourism revenues (REV), and GDP. Specifically, we explore GDP EKC, tourism EKC, and CR EKC hypotheses and reveal non-linear and asymmetric relationships among them. Moreover, empirical findings from a non-linear model allow for more detailed policy implications (Destek and Okumus, 2019).

Third, previous studies either research a single country (Hassan et al., 2019) or scrutinize countries as a group based on their economic stages (Ozturk et al., 2016; Ulucak and Bilgili, 2018) using a total score of EF to explore the EKC hypothesis; however, due to diverse EF conditions and/or different EF subcomponents, it is likely that the subcomponents of EF or different quantiles of EF exhibit different features in nature, and such variances may crucially influence the findings. As we are not certain whether the EKC association is different across various EF quantiles and EF components, QR and the six components of EF are thus used to observe the diverse features across different EF distributions and categories. Therefore, this paper provides fresh and particular evidence on the environmental impacts of economic development, tourism development, and CRs in terms of EFs. By considering the non-linear and/or asymmetric relationships between variables across quantiles and diverse EF subcomponents, we take advantage of the QR approach to supplement past studies and shed light on the effect of the different dimensions of GDP, REV, and CR on EF.

Our research extends the findings of prior empirical studies in this respect by jointly utilizing both longitudinal and international data in order to recognize patterns and changes in EFs. This paper examines how economic development, tourism development, and country risk ratings affect different dimensions and different ecological footprint distribution quantiles of 123 countries for the period 1992–2016. Our results partially support income, tourism, and country risk EKCs (i.e., inverted U-shape relation) exist in grazing land and forest land, signifying that these 2 types of land are sacrifice (increased) and then shift toward enhancing more environmental protection lifestyles as GDP, tourism revenues, and country risk ratings further increase. On the contrary, U-shape relations generally exist in carbon-absorption land, cropland, and fishing ground, implying that growths of tourism, GDP, and country risk ratings have shifted from enhancing more environmentally protection policies to encouraging EF-consuming lifestyles for these EF components. Tourism increases (reduces) fishing ground at lower (higher) fishing quantiles, suggesting the asymmetric impacts of tourism across different quantiles. In addition, we disclose that income development is largely responsible for the EF increases, while tourism generally and saliently decreases forest land and grazing land.

The results herein indicate that tourism, CR, and GDP influence EF inversely under diverse sub-footprints, and that there are noticeably different links across varying EF quantiles. European countries generally support the inverted U-shape relationship. Political risk rating shows a mostly positive impact on EF than those of economic and financial risk ratings, denoting the imperative impact of a country's political rating on environment degradation. These results largely advocate the need for analysis considering the heterogeneities across countries, different EF quantiles, and different EF components in the tourism-, economic-, and country risk-induced EKC estimations. Further test results reveal that the relationships mentioned above are comprehensive when considering the non-financial crisis subperiod, high tourism development countries, low country risk rating countries, developing countries, and European countries.

The remainder of the research runs as follows. Section 2 briefly reviews the literature and hypotheses. Section 3 illustrates the research methodology. Section 4 analyzes the empirical results obtained and presents a discussion. Section 5 concludes the study.

2. Literature review and hypotheses' development

This section presents seven subsections in the sequence of ecological footprint (EF), EKC hypothesis, income-induced EKC hypothesis, country risk rating-induced EKC hypothesis, tourism development-induced EKC, hypotheses' development, and research gap and highlights.

2.1. Ecological footprints

Al-Mulali et al. (2015) and Ulucak and Lin (2017) pinpoint that EF affords a more inclusive and truthful measure than CO_2 emissions for targeting and tracking the influence of a climate change policy. EF denotes the ecological footprint of any given population in a required biological production area for generating the resources consumed by the given population (a person, a city, or a country) and for absorbing all the waste made by the given population (including land and water area) (Kitzes et al., 2007). One may divide EF into six major categories of ecologically productive areas as follows (GFN, 2019).

1) Built-up area (Built): degraded land that is ecologically unproductive, but devoted to the localization of buildings, infrastructures, services, etc.
2) Carbon-absorption land (Carbon): the surface area required to produce, in a sustainable way, the quantity of used energy.
3) Cropland (Crop): the surface area required to grow all the food and non-food products (i.e., cotton, tobacco, etc.) derived from agriculture.
4) Fishing ground (Fish): the marine surface area required to support seafood consumption.

5) Forest (Forest): the area of modified natural systems dedicated to the timber industry.
6) Grazing land (Graze): the surface area required to produce animal products, covering all meat and dairy goods as well as hides and wool.

The formation of the EF design reflects a mutually exclusive use of the above territories, in the sense that each territory is associated with only one activity (GFN, 2019). EF is based on the assumption that most energy and material flows can be transformed into a biologically productive area that is required to support these flows. EF is estimated in "global hectares" (gha), whereby 1 global hectare is equal to 1 ha of biologically productive space with world average productivity (GFN, 2019). The EF indicator captures the multidimensional influence on environmental degradation and is now a critical and powerful indicator for gauging sustainability and environmental quality (Tietenberg and Folmer, 2005). By measuring humans' usage of natural capital as well as comparing resource consumption and waste production to the regenerative capacity of earth, EF is a conventional assessment of human pressure on global ecosystems, and so it can be defined as the portion of carrying capacity needed for that population (Wackernagel et al., 2004).

It is essential that all countries conduct trade-related actions and strategies to raise environmental protection (Ozturk et al., 2016). Therefore, how to reduce EFs entails further exploration for each country. Aydin et al. (2019) indicate that among the EF subcomponents, only fishing ground footprints confirm the income-induced EKC hypothesis. Aşıcı and Acar (2018) reveal that no EKC relationship appears between income and non-carbon footprints. These findings suggest that different EF subcomponents own diverse features and might have different determinates.

2.2. Environmental Kuznets Curve (EKC) hypothesis

According to the description of the EKC hypothesis, environmental degradation increases with the development of an economy, and after economic activity reaches a certain level, environmental degradation starts coming down with further economic progress (Shahbaz and Sinha, 2019). Although EKC appears attractive, the EKC hypothesis and its policy implications have begun to be questioned and critiqued by the theoretical and empirical literature (Chiu, 2012; Stern, 2017). The first of these criticisms is that the shape of a typical EKC curve is based on the assumption that environmental pollution is not cumulative or its effects can be inverted (Fodha and Zaghdoud, 2010). It appeals to those who are paying more attention to environmental situations and environmental quality progress when a country reaches a satisfactorily high standard of living (Cole, 2003). However, the pollution caused by CO_2 emissions is cumulative, and the destruction of biodiversity is irreversible (Fodha and Zaghdoud, 2010).

The second criticism is that the outcomes of empirical studies on EKC may only be effective at the local and regional levels, while perhaps trivial at the global level, because dirty industries that cannot remain in developed economies move to developing countries (Aydin et al., 2019). Hence, the level of pollution may drop in developed countries, but higher levels of environmental degradation may be observed in developing nations that take on new foreign direct investment from such dirty industries (Aydin et al., 2019). In other words, the shape of EKC is an outcome of developed countries exporting pollutants to developing countries that have comparatively weaker environmental regulation (Kearsley and Riddel, 2010). To consider the manufacturing industry feature of developing nations, we conduct the subsample of developing countries and include the control variable of the manufacturing industry.

2.3. Income-induced EKC hypothesis

Lantz and Feng (2006) find that GDP per capita is unrelated to CO_2. Katircioglu (2014) show an inverted U-shape association. Al-Mulali et al. (2015) present that the EKC hypothesis does not exist, because the association between GDP and pollution is positive in both the short run and long run. Ozturk et al. (2016) explore the EKC hypothesis by utilizing the sum of EF components as an environment indicator and GDP from the tourism sector and its square as an economic indicator, noting that EKC between GDP from the tourism sector and EF is only present in upper middle- and high-income nations. Aydin et al. (2019) assert that the inverted U-shape association might be valid for the emissions of pollutants, but might not be valid for resource stocks. Therefore, the findings of the GDP EKC hypothesis are not consistent. However, Destek and Sinha (2020) show that income and EF have a U-shape nexus, which signifies that EF might rise after a certain level of threshold income. Lantz and Feng (2006) find that previous studies may have misspecificed the application of a linear relation between CO_2 emissions and GDP variables. Distributional heterogeneities might exist across different quantiles of EF, and we thus examine the GDP EKC hypothesis with an emphasis on the EF subcomponents by considering the possible non-linear and asymmetric relation between income and EF.

2.4. Country risk-induced EKC hypothesis

Several research studies hold that the influence of economic development on environmental pollution is associated with institutional environments. The policy on environmental protection closely connects with the national background of a certain country (i.e. the political and institutional environments), especially with powerful political parties (Wen et al., 2016). The institutional environment specifies the sets of rules, laws, regulations, customs, practices, and procedures that affect human behavior within an economic system (Martin and Sunley, 2006). Dasgupta and Mäler (1995) address that "*the connection between environmental protection and civil and political rights is a close one. As a general rule, political and civil liberties are instrumentally powerful in protecting the environmental resource base, at least when compared with the absence of such liberties in countries run by authoritarian regimes.*" Cheung and Chan (2011) reveal that the positive impacts of CR can be felt earlier, because CR is like other utilities such as water, electricity, and transportation. As fixed investment has positive effects on economic development, investment in public infrastructure such as CRs can also enhance growth (Kpodar and Andrianaivo, 2011). Furthermore, Romuald (2011) claims that many environmental issues can be illuminated by bad government and institutional failure. Dasgupta and De Cian (2018) show that the effects of environmental interventions depend on the political environment that leads to a policy choice.

Numerous studies have explored the association between environmental pollution and country-related variables, such as democracy (You et al., 2015; Usman et al., 2019), corruption (Arminen and Menegaki, 2019), and civil liberties (Carlesson and Lundström, 2001), among others. Lau et al. (2014) find a positive and noteworthy interaction term between carbon dioxide emissions and institutional quality factors (i.e., law and order), implying that good institutional quality is imperative for controlling carbon dioxide emissions along the path of economic development - that is, institutional quality not only influences economic development directly, but also indirectly via carbon dioxide emissions (Lau et al., 2014). Cervelló-Royo et al. (2016) find a strong association between environmental awareness, country risk rating, and tourism activity that clearly give rise to policymaking implications. Until now, scant research addresses about country risk rating EKC, which deserves an in-depth investigation, because country risks, such as political stability, economic volatility, and financial unrest, might alter environmental quality and degradation. Hence, we explore the CR EKC hypothesis via CRs and the squares of CRs to examine the existence of a non-linear relationship between EF and CR.

2.5. Tourism-induced EKC hypothesis

Most tourism-related activities involve energy directly in the form of fossil fuels or indirectly in the form of electricity frequently produced from petroleum, coal, or gas, from which their consumption causes environmental degradation (Raza et al., 2017). With the speedy development of the tourism sector, ecological security started due to the popularity of tourism seeing more and more attention (Liu et al., 2016). As tourism is a main contributor to climate change, EF is a valuable measure to assess the sustainability of tourism activities (Liu et al., 2016). Prior studies specify that the tourism EKC is a broadly discussed area of dispute in the last decade. For example, Katircioglu (2014) confirms the tourism EKC hypothesis for the case of Singapore. Ozturk (2016) find that international tourism is a motivating factor of the environmental indicator and show the inverted U-shape EKC hypothesis exists more so in upper middle- and high-income countries. Malik et al. (2016) study the long-run relationship between international tourist arrivals and environmental degradation and find that inbound tourism significantly increases CO_2 emissions in the short run, while in the long run this effect vanishes. Becken and Patterson (2006) assess carbon footprints from the tourism sector and draw policy implications for sustainable tourism development internationally. Lee and Brahmasrene (2013) find that tourism has a positive and noteworthy association with economic development, while it has a negative effect on carbon dioxide emissions. De Vita et al. (2015) support the EKC hypothesis in the case of Turkey, as tourist arrivals and economic development meaningfully influence carbon emissions in the country. Although the results seem to support the tourism EKC hypothesis, to the best of our knowledge, there is no research exploring whether the tourism EKC hypothesis is supported under the six EF subcomponents and whether it is supported across different EF distribution countries.

2.6. Hypotheses' development

Our study hypothesizes that economic development, CR, and tourism development should have inverted U-shape relationships with environmental degradation (i.e. six components of EF). Specifically, economic development can be indicated by GDP, and tourism development is proxied by international tourism revenues (REV). We develop the following three hypotheses to generalize the relationships of economic development, tourism development, and country risks on EF, respectively.

H1. Economic development has an inverted U-shape relationship with ecological footprint.

H2. International tourism development has an inverted U-shape relationship with ecological footprint.

H3. Country risk rating has an inverted U-shape relationship with ecological footprint.

The existing literature generally points to inconsistent results and a lack of any specific consideration to CRs, diverse EF components, as well as different EF quantile distributions. Therefore, this study adds to the literature by comparing the impacts of different individual features on EF components via diverse quantiles. By doing so, we target to find evidence that the impacts of the independent variables are not all the same on different EF components as well as different quantiles of EF. Additionally, non-linear relationships exist between institutional factors, economic development, tourism development, and EF.

2.7. Research gap and highlights

The above discussions of relevant literature demonstrate that there is no existing work in the literature that provides international evidence about non-linear and/or asymmetric impacts of tourism development and country risk ratings on the subcomponents of EF across different EF quantiles to validate the tourism development, country risk rating, and economic development EKC hypotheses. Some works do consider related issues, but they limit their focus to specific country groups. Thus, to fill this gap in the literature, this research validates the tourism development, country risk rating, and economic development EKC hypotheses by using six EF subcomponents via quantile regression.

The objectives of this study are as follows. First, we initially probe the country risk ratings-induced EKC hypotheses as determinants of EF components to complement the existing EKC literature. Second, unlike ordinary least squares regression or a linear assumption, this paper explores possible non-linear or asymmetric relationships among EF, CR, international tourism revenues (REV), and GDP, which allow for more detailed policy making for countries under different EF conditions. Third, we provide longitudinal and international evidence in order to recognize patterns and changes in EFs, while considering the subgroup samples of non-financial crisis subperiod, high tourism development countries, low country risk rating countries, developing countries, and European countries. Finally, due to diverse EF conditions and/or different EF subcomponents, it is likely that the subcomponents of EF or different quantiles of EF exhibit different features in nature, and such variances may crucially influence the findings.

3. Methodology

The proposed method is conducted through an empirical study. The framework of this study (Figure A2) has four phases, starting with data collection and arrangement. Phase II analyzes the data via E-view software. Phase III evaluates the empirical results. Phase IV offers conclusion.

3.1. Data

The year 2016 offers the latest data of EF, while the earliest starting time for data on CR is 1992. Therefore, we match countries having EF data with those countries that have international tourism revenue (REV) and CR data and then use 123 countries' annual panel data over the period 1992−2016 to analyze the influence of tourism development (REV), economic development (GDP), and country risk ratings (ECO, FIN, and POL) on ecological footprint (EF) within the framework of EKC. Therefore, the selections of nations and time period are based on data availability. Table A1 provides the sample countries.

This research conducts empirical analysis mainly using three kinds of indepent variables (i.e., coutnry risk, tourism development, and economic development) taken from two datasets (International Country Risk Gudie and World Bank databank). For dependent variables, we employ six EFs measured in global sectors from the Global Footprint Network (GFN, https://www.footprintnetwork.org) 2019 Dataset, which contains data from 1961 to 2016; i.e., build-up land (Built), carbon-absorption (Carbon), cropland (Crop), fishing grounds (Fish), forest area (Forest), and grazing land (Graze) as the dependent variables. EF, which has been assessed for 152 nations (WWF and UNEP-WCMC, Living Planet Report, World Wide Fund for Nature, Switzerland, 2002), is used in numerous studies to evaluate the environmental sustainability of regions and nations (Wackernagel et al., 1999). The higher a nation's EF is, the greater the environmental damage is that the nation is causing (Ozturk et al., 2016).

This research employs three kinds of independent variables. 1) Following Belloumi (2010) who employs international tourism receipts to explore their relationship with economic development, we use the yearly log of international tourism revenue (REV) in current US$ obtained from the World Development Indicators (WDI) of the World Bank database. 2) In order to examine the EKC hypothesis, we include per capita GDP (GDP) in constant 2010 US$ from WDI. 3) The yearly country risk rating (CR) data are constructed by the International Country Risk Guide (ICRG) of Political Risk Services Group, which comprises three subcategories: economic (ECO), financial (FIN), and political (POL). Political risk compounds the degree of political uncertainty in a given country; economic risk is a measure assessing a country's current economic strengths and weaknesses; financial risk provides a measure of a country's capability to finance its official, commercial, and trade debt obligations (Hayakawa et al., 2013; Lee et al., 2020). Country risk increases as the rating decays. Except for the political risk rating ranging from 0 to 100, financial and economic risk ratings both span from 0 to 50. The economic and financial risk ratings each account for 25%, while the political risk rating comprises 50% of the composite risk rating (Hoti et al., 2007).

ICRG risk ratings have been used by experts at the International Monetary Fund, World Bank, United Nations, and other international institutions as a standard against which other ratings are measured (Suleman et al., 2017). Overall, the creditworthiness of a nation with an increasing risk rating results in higher inflows of foreign capital and investment, which in turn help the country's economic development (Hoti et al., 2007). The studied variables, including country risk ratings, tourism development, and GDP, have a different position in the EKC thesis, because there are numerous prior studies concerning tourism development and GDP variables, however, country risk ratings in the EKC framework have not been previously assessed, which is the novelty of this study. Table A2 offers detailed definitions and sources of the variables in the empirical analysis.

We also comprise a number of control variables in the QR models to strengthen our empirical findings. Bossel (1998) pinpoints that there is an ecological cycle and an economic cycle that go through periods of innovation, renewal and growth, conservation, and deterioration, leading back to innovation again. While the duration of a cycle differs from the inflation rate, the consumer price index and unemployment rate over the past 200 years both disclose a 50-year cycle (Bossel, 1998, p. 65). Frankel and Rose (2005) show the trade factor charged to pollute a country's environment is predominantly in low environmental regulatory nations where economic development outweighs the environment damage. Katircioglu et al., 2018 state that the real exchange rate reveals how the currency exchange rate influences environmental quality, because this rate changes the carbon credit prices through energy commodity markets (Yu and Mallory, 2014). Saud et al. (2020) address that economic development raises industrial production, which spurs resource consumption and environmental deterioration. Charfeddine and Mrabet (2017) find when economic structures switch from agriculture to manufactured goods that environmental damages increase, and in a later stage the decline of heavy manufacturing industries induces a decline in the polluting intensity of real gross domestic product per capita. Therefore, the development of a country's manufacturing industry has a significant impact on the ecological footprint. Following Houseman et al. (2011) and Havlik (2015), we use manufacturing value added in GDP as a control variable to proxy for the manufacturing industry of a country.

We thus consider the influence of economic factors by including CPI (consumer price index (2010 = 100)), EXG (log of official currency exchange rate per US$), IND (log of industrial production in constant US$), INF (inflation, consumer prices in annual %), TRD (trade percentage of GDP), UMP (unemployment, total % of total labor force), and Man (manufacturing value added % of GDP). All data are gathered in US dollars from the World Bank's WDI database.

In addition to a full-sample estimation, we also divide all observations into dissimilar sub-groups to gain further evidence. Tienhaara (2010) shows that the association between financial and environmental crises offers both opportunities and threats to attaining long-term economic and ecological sustainabilities. Therefore, according to Hill et al. (2015) and Johnson et al. (2000), we set the global financial crisis period at 2008–2009 and Asian financial crisis period at 1997–1998 and examine the non-financial crisis period. Moreover, we utilize the mean values of REV and total score of composite risk rating to divide all observations into high REV and low CR subgroups to explore whether the impacts of REV and CR on EF are different from the full sample. According to International Tourism Highlights (2019) from the World Tourism Organization, Europe accounts for half of the world's international arrivals and represents nearly 40% of international tourism receipts. Zaman et al. (2016) find that developing countries are optimistic at capitalizing their synergies between environment and tourism to follow the 'green growth' agenda for protection of natural resources. Therefore, to conduct robustness tests we divide the sample data into five subgroups: developing country, non-financial crisis period, high REV, low country risk rating, and European countries.

Table 1 offers summary statistics of our main variables. We realize from Table 1 that REV varies between 13.72 and 24.94 during the sample period, with the median being 21 and the average being 20.8. EF sums the demands that human activities place on the earth's productive areas. Fig. 1 depicts the area chart of these components' size (per capita) for 1992–2016. Among the ecological footprint components, the shares of carbon, cropland, grazing area, forest, built-up land, and fishing ground in total EF are 55%, 18%, 9%, 12%, 2%, and 4%, respectively. The greatest share is the carbon footprint, exposing the results that carbon footprint as a whole has more primacy. Ulucak and Lin (2017) also note that the carbon footprint is the largest of the EF components for the U.S.

Before estimation, the correlation matrix is checked to confirm that collinearity is not a problem. Table 2 displays the unconditional correlation between variables. The correlations between GDP increase along with a rise in EF, REV, and CR. REV increases along with CR and EF (except for grazing land footprint). As far as the relationship between EF and other factors is concerned, the following outcomes are indicated: INF, TRD, and UMP decrease built-up land, while others increase it; EXG, INF, and UMP decrease carbon, while others increase it; EXG, IND, INF, and TRD decrease cropland, while others increase it; grazing land, EXG, INF, UMP, and MAN decrease fishing ground, while others increase it; FIN, CPI, EXG, IND, INF, and MAN decrease forest, while others increase it; and REV, FIN, CPI, IND, INF, trade, and MAN decrease grazing land, while others increase it.

Table 1
Descriptive statistics.

Variable	Mean	Median	Max	Min	Std	Skew	Kurtosis	Jarque-Bera	Obs.
Built	0.06	0.05	0.25	0.00	0.04	1.64	6.10	2097.94	2463
Carbon	1.86	1.10	15.42	0.02	2.00	2.04	9.78	6416.29	2464
Crop	0.59	0.56	1.97	0.09	0.27	0.72	3.26	217.55	2463
Fish	0.14	0.06	3.61	0.00	0.27	7.63	80.16	634943.60	2463
Forest	0.41	0.30	3.37	0.00	0.38	3.06	17.51	25457.48	2463
Graze	0.29	0.20	5.17	0.00	0.32	3.66	31.01	85990.00	2463
REV	20.80	21.00	24.94	13.72	2.14	−0.45	2.80	91.06	2576
ECO	34.57	35.00	50.00	0.00	6.78	−0.92	5.06	949.38	2993
FIN	36.37	37.00	50.00	4.00	6.95	−1.00	4.86	931.17	2993
POL	65.64	65.50	97.00	1.50	13.37	−0.35	3.32	73.14	2993
GDP	8.57	8.57	11.42	5.30	1.47	−0.05	2.01	120.93	2956
CPI	78.97	82.04	349.82	0.00	34.56	0.40	6.89	1854.70	2820
EXG	2.97	2.42	22.63	−15.20	2.94	0.08	4.00	116.77	2741
IND	29.07	26.76	87.80	2.07	11.91	1.51	6.14	2249.20	2839
INF	24.63	4.30	4734.91	−16.12	183.75	16.37	326.74	12467621.00	2826
TRD	80.91	71.12	437.33	0.02	47.67	2.62	14.60	19700.11	2918
UMP	8.35	7.22	33.47	0.15	5.21	1.26	5.22	823.58	1751
MAN	16.55	16.80	31.37	1.60	6.24	0.01	2.53	7.86	857

Notes: The yearly data in this study span from 1992/01/01 to 2016/12/31. 'Min', 'Max', and 'Std' are respectively the minimum, maximum, and standard deviation. The six ecological footprint factors are Built (built-up land), Carbon (carbon-absorption land), Crop (cropland), Fish (fishing ground), Forest (forest land), and Graze (grazing land). REV is log of international tourism revenue. The three country risk factors are ECO (economic risk rating), FIN (financial risk rating), and POL (political risk rating). The control variables are CPI (consumer price index), EXG (log of official currency exchange rate per US$), GDP (log GDP per capita of country), IND (log of industrial production), INF (inflation, consumer prices of annual %), TRD (sum of exports and imports of goods and services), UMP (unemployment, total % of total labor force), and MAN (Manufacturing, value added % of GDP). The Jarque-Bera (JB) statistics of all variables indicate departures from normality and present the existence of non-linear components in the data-generating process.

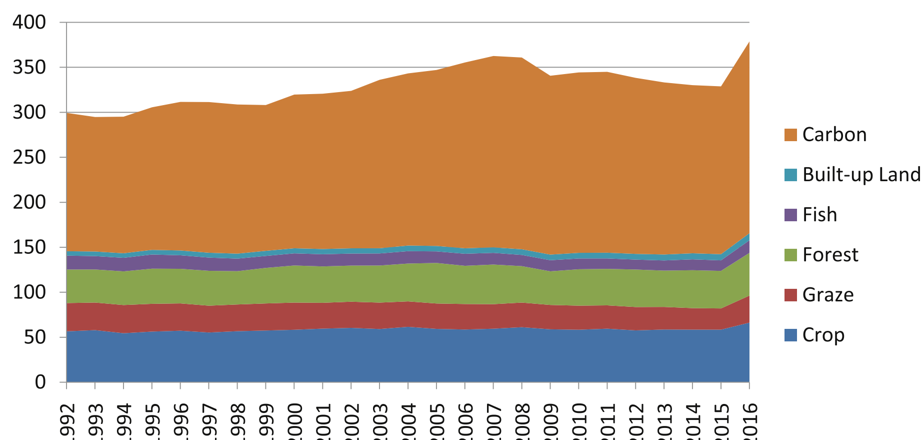

Fig. 1. Ecological footprint by component for the sample countries from Global Footprint Network.

Table 2
Unconditional correlation.

	Built	Carbon	Crop	Fish	Forest	Graze	REV	ECO	FIN	POL	GDP	CPI	EXG	IND	INF	TRD	UMP	MAN
Built	1.00																	
Carbon	0.13	1.00																
Crop	0.30	0.49	1.00															
Fish	0.05	0.09	0.13	1.00														
Forest	0.29	0.28	0.44	0.13	1.00													
Graze	0.08	0.02	0.00	−0.03	0.13	1.00												
REV	0.17	0.52	0.40	0.13	0.10	−0.15	1.00											
ECO	0.10	0.54	0.23	0.36	0.23	0.07	0.40	1.00										
FIN	0.06	0.30	0.03	0.30	−0.06	−0.02	0.28	0.59	1.00									
POL	0.24	0.58	0.46	0.33	0.46	0.11	0.44	0.55	0.26	1.00								
GDP	0.28	0.77	0.59	0.35	0.43	0.09	0.65	0.59	0.36	0.77	1.00							
CPI	0.10	0.19	0.05	0.02	−0.01	−0.05	0.28	0.18	0.32	0.05	0.20	1.00						
EXG	0.06	−0.29	−0.31	−0.01	−0.23	0.02	−0.18	−0.12	0.00	−0.35	−034	0.03	1.00					
IND	0.03	0.23	−0.09	0.10	−0.15	−0.09	0.13	0.30	0.35	−0.06	0.07	0.00	0.11	1.00				
INF	−0.06	−0.15	−0.03	−0.08	−0.06	−0.03	−0.16	−0.32	−0.30	−0.23	−0.18	−0.35	−0.04	0.06	1.00			
TRD	−0.07	0.25	−0.04	0.03	0.09	−0.10	0.06	0.29	0.21	0.25	0.17	0.09	−0.25	0.12	−0.09	1.00		
UMP	−0.05	−0.16	0.11	−0.20	0.06	0.01	−0.22	−0.26	−0.27	−0.05	−0.05	−0.11	−0.11	−0.22	0.00	−0.05	1.00	
MAN	0.16	0.10	0.01	−0.03	−0.03	−0.31	0.27	0.13	0.10	0.10	0.03	−0.17	0.13	0.36	0.00	0.26	−0.23	1.00

Notes: The same as the notes in Table 1.

We observe different relationships exist among different EF components with other variables, and therefore we use every single EF component rather than the total EF score. REV is positively related with all CR variables, suggesting that creditworthy countries obtain more REV. The negative association of EXG with REV is consistent with Forsyth et al. (2014) in that an increased exchange rate places intentional visits to Australia at a competitive disadvantage, dropping international leisure tourism demand. The panel unit test results show a uniform conclusion that the null of the unit root can be rejected for the levels of the factors, which propose that the variables are stationary in level form. From unit root analysis, we conclude that the variables are integrated of order zero, suggesting a possible long-run association among them.[2]

3.2. Models

In the empirical pursuit, we utilize the EKC framework proposed by Grossman and Krueger (1991). With the validation of time, the EKC hypothesis has marked its place in the works of economic development and environmental economics. Finding a robust sign of violation of the assumption of homoscedastic variance in the classical linear regression model, Du and Ng (2018) use quantile regression to probe the existence of a negative economic effect of climate change on tourism economies. Using the quantile regression test, Mills and Waite (2009) explore the EKC hypothesis, employing estimates of per capita income and deforestation rates, and find that utilizing conventional regression techniques fails to offer any backing for the parabolic association predicted by the EKC hypothesis. Mills and Waite (2009) encourage the usage of quantile regression in EKC analyses, because quantile regression offers a more complete picture of the association than does conventional regression. Conventional OLS affords summary point estimations for the mean results of the explanatory variables (Binder and Coad, 2011). Concentrating on the average effects may under- or overestimate the related coefficient estimates or may even fail to identify vital relations (Binder and Coad, 2011). To consider these issues, we employ QR proposed by Koenker and Bassett (1978), which is more robust and consequently offers more efficient estimations, since it permits us to include a full range of conditional quantile functions (Chiang et al., 2010). Furthermore, it is robust to heteroskedasticity, skewness, and leptokurtosis, which are general features of financial data (Baur et al., 2012).

The study tailors Eq. (1) with respect to the 'reduced form of EKC' in which different variables enter the domain of GDP, country risk ratings, and tourism development as follows.

$$\mathrm{EF_{it}} = \beta_0 + \beta_1 \mathrm{REV_{i,t}} + \beta_2 \mathrm{CR_{i,t}} + \beta_3 \mathrm{GDP_{i,t}} + \beta_4 \mathrm{GDP^2_{i,t}} + \beta_5 \mathrm{CV_{i,t}} + \varepsilon_{\mathrm{it}} \tag{1}$$

Here, $\mathrm{REV_{it}}$ denotes country *i*'s international tourism revenues in time *t*, while CR represents the three country risk ratings: ECO (economic), FIN (financial), and POL (political). GDP indicates log of GDP per capita, while GDP^2 indicates the square of the log GDP per capita of a country. CV denotes the six control variables that might influence the relationships between GDP and EF: CPI (consumer price index 2010 = 100), EXG (log of official currency exchange rate per US$), IND (log of industrial production in constant US$), INF (inflation, consumer prices in annual %), TRD (sum of exports and imports of goods and services), UMP (unemployment, total % of total labor force), and MAN (manufacturing value added in GDP).

Aside from Eq. (1), the study estimates the EKC hypothesis on the promise of tourism development and specifies the model as Eq. (2).

$$\mathrm{EF_{it}} = \beta_0 + \beta_1 \mathrm{CR_{i,t}} + \beta_2 \mathrm{GDP_{i,t}} + \beta_3 \mathrm{REV_{i,t}} + \beta_4 REV^2_{i,t} + \beta_5 \mathrm{CV_{i,t}} + \varepsilon_{\mathrm{it}} \tag{2}$$

Here, REV^2 indicates the square of the square of international tourism revenues. Aside from Eq. (1), the study also estimates the EKC hypothesis on the promise of country risk ratings and specifies the model as Eq. (3).

$$\mathrm{EF_{it}} = \beta_0 + \beta_1 \mathrm{REV_{i,t}} + \beta_2 \mathrm{GDP_{i,t}} + \beta_3 \mathrm{CR_{i,t}} + \beta_4 CR^2_{i,t} + \beta_5 \mathrm{CV_{i,t}} + \varepsilon_{\mathrm{it}} \tag{3}$$

Here, CR^2 indicates the square of the country risk ratings. Equations (1)–(3) show the EKC equation in which GDP and GDP^2, REV and REV^2, and CR and CR^2 are evaluated into the following five possibilities (Zaman et al., 2016).

i) $\beta_3 = \beta_4 = 0$, showing flat/no association between GDP (REV, CR) and EF.
ii) $\beta_3 > 0$, $\beta_4 = 0$, showing GDP (REV, CR) has a noticeable positive value, while square of GDP (REV, CR) has an insignificant value, thus concluding that there is a monotonically increasing association between EF and economic development.
iii) $\beta_3 < 0$, $\beta_4 = 0$, showing GDP (REV, CR) has a noticeably negative value, while the square of GDP (REV, CR) has an insignificant value, thus concluding that there is a monotonically decreasing association between EF and economic development.
iv) $\beta_3 > 0$, $\beta_4 < 0$, showing GDP (REV, CR) has a noticeably positive value, while the square of GDP (REV, CR) has an significant negative value, thus confirming the inverted U-shape association between EF and economic development (EKC).
v) $\beta_3 < 0$, $\beta_4 > 0$, showing GDP (REV, CR) has a noticeably negative value, while the square of GDP (REV, CR) has a significant positive value, thus confirming the U-shape association between EF and economic development.

We assess Eqs. (1)–(3) by the QR approach and consider the influences of economic development, tourism, and country risk rating variables on dependent variables' (Ys) dynamics by accounting for that the conditional ∂.quantile of Ys' change distribution (y_t), $Q_y(\partial|x)$, is influenced by the effects from independent variables and other control variables. Hence, we specify the ∂^{th} conditional quantile function of *y* as:

$$\mathrm{Q_y}(\partial|\mathrm{x}) = \inf\{\gamma|\mathrm{F_y}(\gamma|\mathrm{x}) \geq \partial\} = \sum_{\mathrm{h}} \alpha_{\mathrm{h}}(\partial)\mathrm{x_h} = \mathrm{x}\alpha(\partial) \tag{4}$$

Here, $F_y(\gamma|x)$ is the conditional distribution function of *y* given *x*, and the QR coefficient $\alpha(\vartheta)$ determines the dependence association between vector *x* and the ∂^{th} conditional quantile of *y*. Dependence is unconditional if no exogenous variables are comprised in *x*, while it is conditional if exogenous variables are included into *x*.

The values of $\alpha(\vartheta$ for $\vartheta \in [0, 1]$ decide the complete dependence structure of *y*. The coefficients $\alpha(\vartheta)$ for a given ∂ are assessed by minimizing the weighted absolute deviations between *y* and *x*:

[2] Probabilities for the Levin, Lin, and Chu tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality. The maximum lag lengths are automatic selection, and the Schwarz Bayesian Criterion is used to determine the optimal lag length. Due to space limitation, the results of unit root tests are available upon request from the authors.

$$\widehat{\alpha}(\partial) = \text{argmin} \sum_{t=1}^{T} \left(\partial - 1_{\{y_t < x_t^{'}\alpha(\partial)\}} \right) |y_t - x_t^{'}\alpha(\partial)| \quad (5)$$

Here, $1\{y_t < x_t^{'}\alpha(\partial)\}$ is the usual indicator function. The resolution to this problem is attained using the linear programming algorithm proposed by Koenker and D'Orey (1987). The standard errors for the estimated coefficients can be obtained from the pair bootstrapping procedure suggested by Buchinsky (1998) since it offers standard errors that are asymptotically valid under heteroscedasticity and misspecifications of the QR function. In the case of linear dependence on a vector of exogenous variables (X), we compose the linear conditional quantile function as:

$$Q(\partial|x) = \beta(\partial) + \sum_{h} \gamma_h(\partial) x_h \quad (6)$$

The vector of exogenous variables in this study comprises GDP, REV, and CR variables, dependent variables (EF), and control variables. We evaluate dependent variables across five quantiles $q = \{0.1; 0.25; 0.5; 0.75; 0.9\}$. Note that the values of $\gamma(\partial)$ characterize the GDP, REV and CR effects. Thus, if these values do not vary across quantiles, then the dependence structure is said to be constant; if they decrease (increase) across quantiles, then the dependence structure is said to be decreasing (increasing); and if they are dissimilar (similar) for low (high) quantiles, then the dependence structure is said to be asymmetric (symmetric).

4. Empirical results and discussions

4.1. Results of the EKC hypothesis

We explore the non-linear effects of GDP and GDP^2 by analyzing across different EF distributions. Fig. 2 shows graphical findings of the GDP-EF relation for the QR parameter estimates and 95% confidence intervals. Coefficient estimates are on the vertical axis, while the quantile index is on the horizontal axis. The impacts of GDP and GDP^2 at different quantiles of the EF distribution for different EF components are displayed in Fig. 2a−f. As can be seen, the intensity of the effects varies across the entire spectrum of quantiles. The estimation and testing results indicate that the effects of different GDP and GDP^2 on EF are quite heterogeneous. The effects of ECO, FIN, and POL are different across varying EF components and different across the EF quantiles, suggesting that the influences of CR on EF do not merely allow us to observe the total scores of EF. Additionally, REV generally shows a negative impact on higher EF quantiles, suggesting that countries with sustainable tourism (lower EF) obtain more international tourism revenues. The results indicate that the influences of GDP and GDP^2 are non-linear and diverse across different EF subcomponents and different quantiles.

Table 3 reports the QR parameter estimates for the impacts of GDP and GDP^2 on different EF at the 10th, 25th, 50th, 75th, and 90th levels. All coefficients of GDP and GDP^2 are significant at the 1% level for the 10th-90th quantiles in carbon footprint. Moreover, since the assessed coefficients of GDP are lower than zero and the assessed coefficients of GDP^2 are greater than zero, the results do not support the claim that an inverted U-shape relationship between economic development and carbon footprint exists, but our results support a U-shape relationship. Fishing ground, built-up land, cropland, and GDP also show a U-shape relationship across most of the quantiles, and thus the results do not support EKC hypothesis. A U-shape relationship implies that GDP growth has shifted from enhancing more environmentally protective policies (Kaufmann et al., 1998) to encouraging EF-consuming lifestyles (Shafik, 1994). The EKC hypothesis is supported only at all grazing land and the 0.75 quantile of forest land, indicating that GDP growth, while tending at first to raise EF in order to supply the needed goods and services in the economy (Cropper and Griffiths, 1994), ultimately forces EF to drop due to improved environmental conservation as the economy grows (Seldon and Song, 1994). These results indicate that heterogeneity exists in different EF subcomponents and in diverse quantiles. As such, it is inappropriate to use the conditional mean method to represent the relationship between GDP and EF; instead it should be analyzed with a method such as quantile regression according to different levels of EFs. Likewise, Bimonte and Stabile (2017) find a U-shape relationship between consumption and GDP. The non-linear GDP and EF findings differ from previous studies that may have misspecified by assuming linear functional forms.

Regarding tourism revenues, we observe that the effects of REV on EF are significantly positive (negative) for cropland (built-up land, forest land, and grazing land). However, fishing land shows significantly negative (positive) impacts at the higher highest (lower) quantile, revealing that lower fishing ground quantile countries consume more fish resources as tourism revenues rise. These results denote that tourism decreases or increases different EF subcomponents and across different EF quantiles. In addition, we observe that most of the effects of REV on EF is significantly positive at the lowest quantile, but significantly negative at the higher quantile, except for the impacts on graze, which are all negative. The results also reveal that tourism exacerbates environmental degradation in the lowest EF countries, but has negative noteworthy impacts on the environmental degradation of countries with higher EF. Our results spotlight that tourism development in countries with the lowest EF increase the requirements of EF, whereas it is possible that the EF ceiling effect arrives to decrease the EF consumed for higher EF countries.

With respect to CR, the results provide evidence that POL significantly positively influences EF, implying that POL may worsen environmental quality. However, ECO and FIN do not show consistent impacts across EF quantiles. The finding indicates that EF is more positively associated with POL than with ECO and FIN, indicating a nation's policy setting fairly increases EF. Likewise, Wang et al. (2018) find that democracy may worsen environmental quality. Considering the control variables, the UMP (MAN) effect on EF is more obviously negative (positive), meaning UMP plays a critical role at reducing (increasing) EF. TRD have a positive effect on carbon, fishing, and forest footprints, but a negative effect on built-up land and cropland footprints. CPI and EXG show positive and negative impacts across different EF components and EF quantiles, respectively. IND shows a positive impact on built-up land and carbon, but a negative impact on fishing ground and grazing footprints, indicating it is inappropriate to explore EF via its total sum due to different features among the six components of EFs. In sum, our findings only partially support H1 that GDP has an inverted U-shape relationship with grazing land and the highest quantile of forest land.

4.2. Tourism EKC hypothesis

Table 4 shows quantile estimates from Eq. (2) and the QR parameter estimates for the impacts of REV and REV^2 on different EF at the 10th, 25th, 50th, 75th, and 90th levels. Most coefficients of REV and REV^2 are significant for carbon, crop, fish, and graze ecological footprints. Moreover, because the estimated coefficients of REV on lower and intermediate graze (lower built-up as well as intermediate and higher levels of fish) are higher than zero and the estimated coefficients of REV^2 are lower than zero, the results partly support the claim that an inverted U-shape relationship

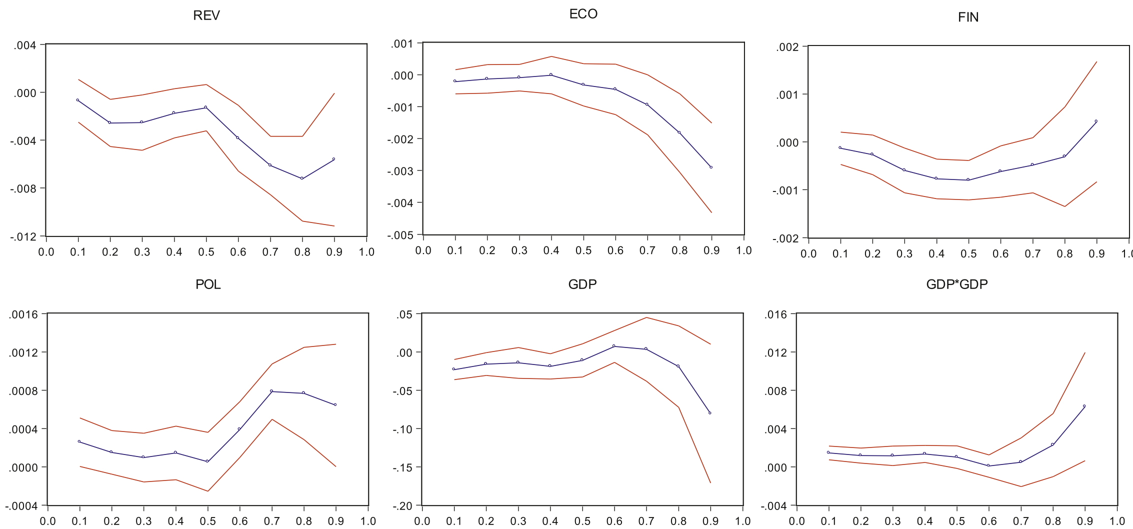

Figure 2a. The impacts of tourism development and country risk rating on built-up land.

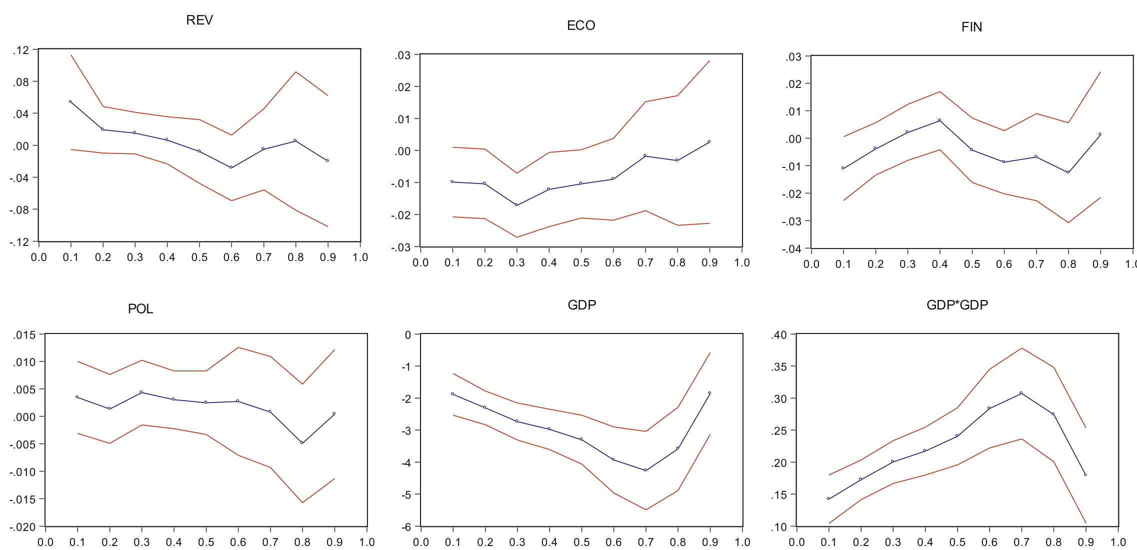

Figure 2b. The impacts of tourism development and country risk rating on carbon-absorption land.

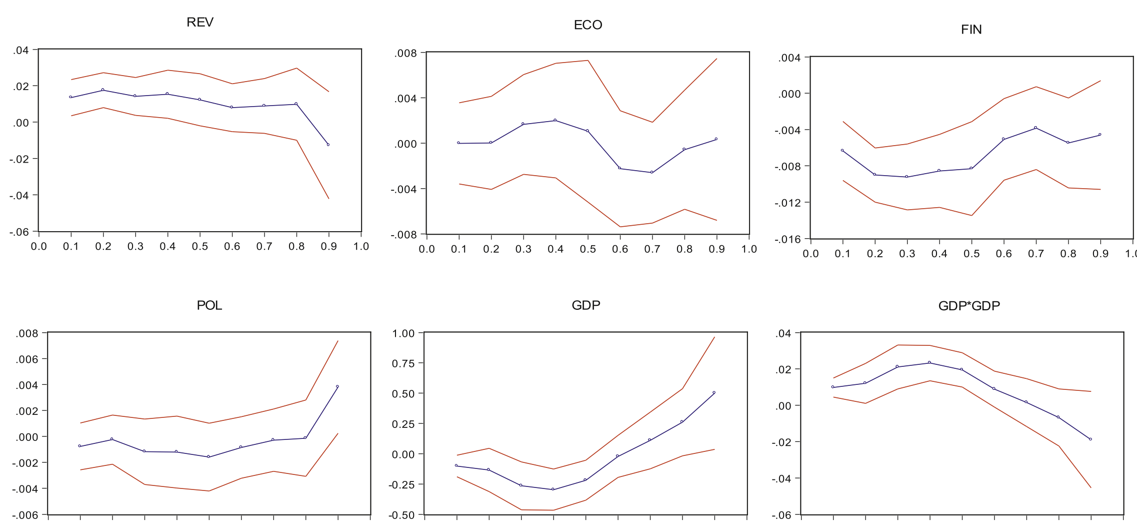

Figure 2c. The impacts of tourism development and country risk rating on cropland.

Fig. 2. a. The impacts of tourism development and country risk rating on built-up land.
b. The impacts of tourism development and country risk rating on carbon-absorption land.
c. The impacts of tourism development and country risk rating on cropland.
d. The impacts of tourism development and country risk rating on fishing grounds.
e. The impacts of tourism development and country risk rating on forest area.
f. The impacts of tourism development and country risk rating on grazing land.
Notes: Quantile regression estimates. The middle line shows the quantile regression estimates for the quantile ranging from 0.1 to 0.9, and the upper and lower lines depict 90% confidence intervals for the quantile regression estimates.

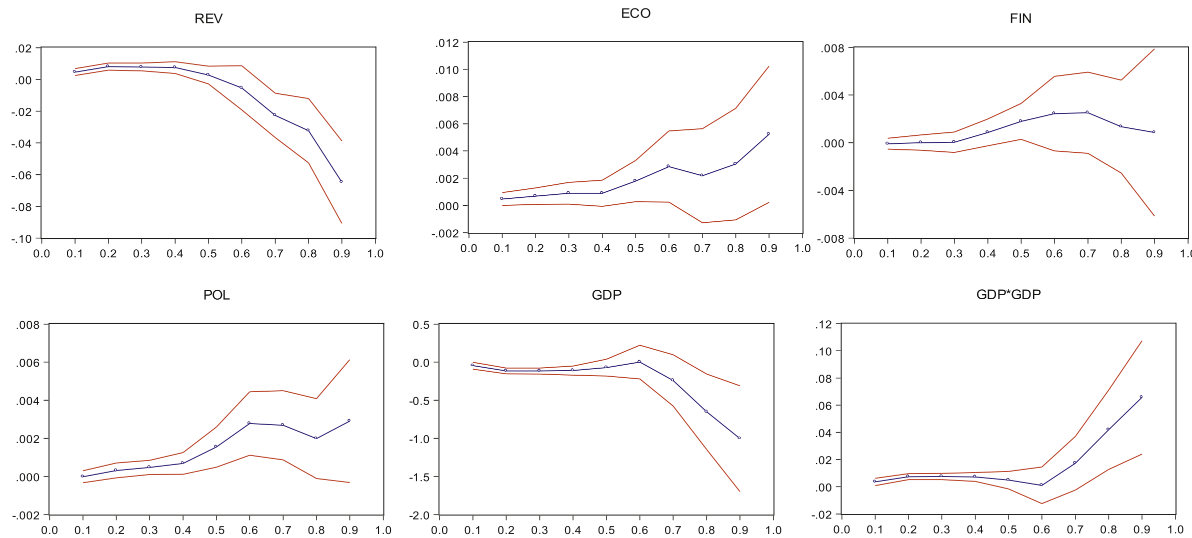

Figure 2d. The impacts of tourism development and country risk rating on fishing grounds.

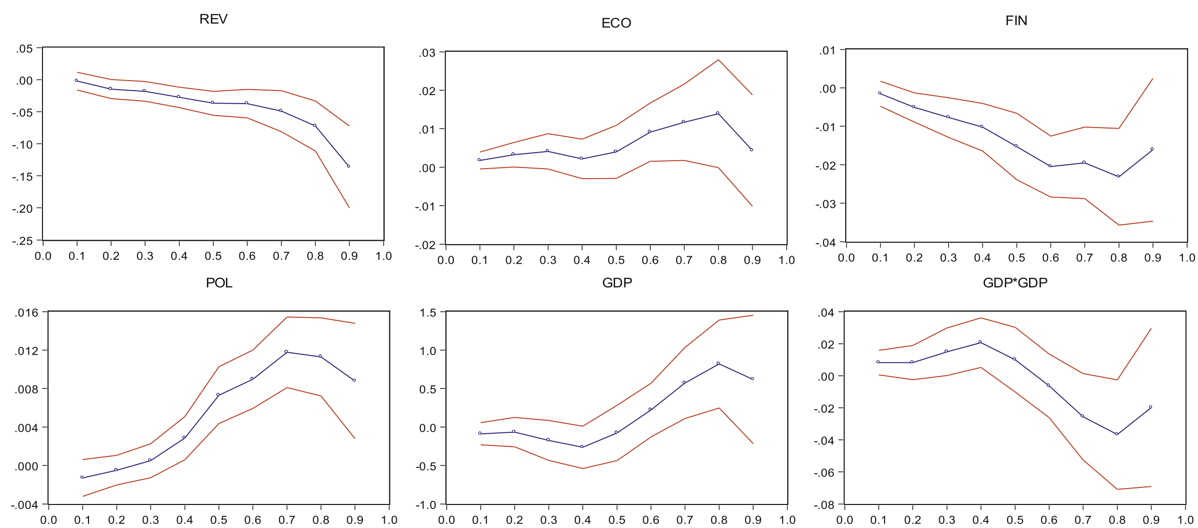

Figure 2e. The impacts of tourism development and country risk rating on forest area.

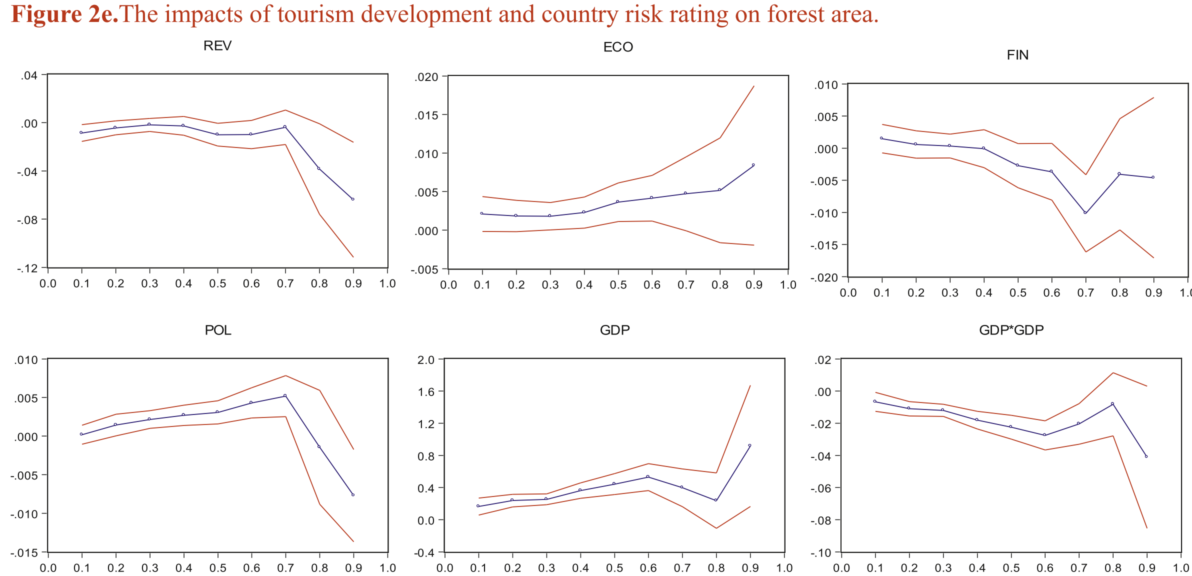

Figure 2f. The impacts of tourism development and country risk rating on grazing land.

Fig. 2. (*continued*).

exists between tourism development and EFs (i.e. built-up, fish, and graze footprints). They imply that tourism growth, while tending at first to raise EF in order to supply the needed goods and services in the economy (Cropper and Griffiths, 1994), ultimately forces EF to drop due to improved environmental conservation as tourism grows. Conversely, the countries with all carbon quantiles, cropland at 10th-50th quantile, and forest 25th quantile show a U-shape relation, thus rejecting the EKC hypothesis. Generally, the U-shape relationship implies that tourism changes shift from enhancing more environmentally friendly policies to encountering increased EF; as the later stage of tourism increases, EF also increases. The result may also indicate that when the impacts of REV on EF reach their peak of EF consumption, the impacts turn into a different sign. Because REV shows U-shape and inverted U-shape impacts for different footprints and across different quantiles, these results specify that heterogeneity does exist under those cases. Additionally, different features exist within diverse EF subcomponents, indicating that using the total score of EF offers only limited context.

Regarding GDP, we observe that most effects of GDP on EF are significantly positive across all EF quantiles, except only that the impact on built-up land at the lowest quantile is insignificant. This indicates that GDP exacerbates environmental degradation in all countries. Our results can be explained in that GDP increases the requirements of EFs, and that as countries increase GDP, it worsens environmental quality.

With respect to CR, we see from the results in Section 4.1 that POL significantly positively influences EF, implying POL may worsen environmental quality. FIN fairly significantly negatively influences EF, implying FIN may improve environmental quality. In line with the findings of Section 4.1, POL (FIN) generally shows positive (negative) impacts across EF quantiles. ECO shows positive impact on EF. These findings suggest that growths of POL and ECO company with environment degradation, whereas FIN reduces EF consumption. Moreover, EF is more strongly associated with POL than with ECO and FIN. Since a higher risk rating indicates lower country risk, the results suggest that countries with lower political and economic country risks have higher environmental degradation. Likewise, Wang et al. (2018) find that democracy may worsen environmental quality. On the other hand, countries with higher financial country risk ratings have lower environmental degradation, revealing countries with lower financial risk have better environmental quality.

Considering the control variables, we observe that the TRD, UMP, MAN, EXG, and CPI effects on EF are positive and negative across different subcomponents and different quantiles. Specially, non-linear and asymmetric relationships are observed in most of the correlations between EF and the control variables. For example, CPI shows positive effects at lower quantiles of carbon, fish, and graze, but negative effects at their higher quantiles. This indicates that it is inappropriate to explore EF via its total sum and/or linear regression due to different features among the six components of EF and different EF quantiles. In total, our findings do support H2 that international tourism revenues have an inverted U-shape relationship with lower quantile of built-up land, intermediate and higher quantiles of fish, as well as lower and intermediate quantiles of grazing footprints.

4.3. Country risk rating EKC hypothesis

Table 5 lists the results of the non-linear relationship between CR and EF on the country risk rating EKC hypothesis. Only graze at the highest quantile and forest at the 75th quantile support the ECO-induced ECK hypothesis, while the forest intermediate and the 75th quantiles support the FIN-induced EKC hypothesis. However, the results generally show a U-shape relationship between forest, carbon, and crop and CR (i.e., ECO and POL). A U-shape relationship implies that ECO and POL changes have shifted from being more environmentally friendly to encountering an EF increase; during the later stages of POL and ECO increases, EF also increases, implying that ECO growth and POL growth have moved from increasing more environmentally protection policies (Kaufmann et al., 1998) to inspiring EF-consuming lifestyles (Shafik, 1994) as ECO and POL increase. Likewise, Wang et al. (2018) show that rises in democracy and political globalization degrade environmental quality. Conversely, Yasin et al. (2019) find that political institutions have a constructive environmental effect, as they use the sum of EF, rather than individual components of EF. Our results show that heterogeneity does exist in different EF components and in diverse quantiles. It is thus inappropriate to use the conditional mean method or a total EF score to represent the relationship between CR and EF. Instead, one should analyze the relationship with a method such as quantile regression according to diverse quantiles of the subcomponents of EF. Additionally, the non-linear impact of country risk rating on EF finding fills the gap in environmental economic research.

Regarding tourism revenues, we observe that the effects of REV on EF are considerably negative on the built-up, forest, and graze footprints, but considerably positive on the cropland footprint. However, there is a positive (negative) effect of REV on lower (higher) fish quantiles, signifying tourism exacerbates environmental quality in the lower fish EF countries, but has negative substantial impacts on the environmental degradation of nations with larger fish footprint. Our results can be explained by tourism development in nations having the lowest EF increases the requirements of fish EF, whereas it is possible that fish EF reaches its peak and then decreases as EF is consumed, or countries with increased REV are more aware about the importance of environmental quality.

Regarding GDP, we observe that all salient effects of GDP on EF are positive across all EF quantiles, indicating that GDP worsens environmental quality in all countries. Our results can be explained in that GDP increases the requirements of EFs, and as countries increase GDP, it worsens their environmental quality. Considering the control variables, the same result arises in Sections 4.1 and 4.2 in that the UMP effect on EF is more obviously negative, denoting that UMP plays a critical role in reducing EF. MAN has generally positive effects on built-up land, carbon-absorption land, and cropland, while negative effects on fish, forest, and graze footprints. TRD generally has a positive (negative) effect on carbon and fishing (built-up and cropland), while an asymmetric effect on graze. EXG and IND also show positive and negative impacts across different EF components, indicating it is inappropriate to explore EF via its total sum due to different features among the six components of EFs. Overall, our findings support H3 that an inverted U-shape relationship exists between country risk rating and ecological footprint only for the higher quantiles of forest and graze on the ECO-induced EKC hypothesis, as well as intermediate and higher quantiles of forest on the FIN-induced EKC hypothesis.

4.4. Robustness checks

4.4.1. Further evidence for the subgroup of high international tourism revenue countries

To further identify the possible differences between high and low REV countries, we estimate the mean value of countries' REV and select the high REV countries to run QR in Table 6. Inverted U-shape relationships exist in carbon, crop, and fishing footprints, whereas U-shape relationships exist in built-up, forest, and grazing footprints. The results imply that GDP growth has moved from

Table 3
Estimates of the QR-based economic-induced EKC hypothesis on ecological footprint models (Eq. (1)).

Variable	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90
	Built					Carbon					Crop				
C	0.114***	0.107***	0.048	0.089	0.379**	5.381***	8.300***	9.898***	12.284***	1.202	0.359	0.696	0.695**	−0.659	−1.366*
REV	−0.001	−0.002**	−0.001	−0.008***	−0.006**	0.054*	0.018	−0.008	−0.019	−0.020	0.013***	0.015***	0.012*	0.009	−0.013
ECO	0.000	0.000	0.000	−0.001***	−0.003***	−0.010*	−0.013***	−0.010*	−0.002	0.003	0.000	0.001	0.001	−0.002	0.000
FIN	0.000	0.000**	−0.001***	0.000	0.000	−0.011*	−0.003	−0.004	−0.010	0.001	−0.006***	−0.008***	−0.008***	−0.004	−0.005
POL	0.000**	0.000	0.000	0.001***	0.001**	0.003	0.004	0.002	0.001	0.000	−0.001	0.000	−0.002	−0.001	0.004**
GDP	−0.023***	−0.016	−0.011	−0.016	−0.081*	−1.884***	−2.706***	−3.302***	−4.262***	−1.857***	−0.102**	−0.229**	−0.219***	0.232*	0.500**
GDP^2	0.001***	0.001**	0.001*	0.002	0.006**	0.142***	0.197***	0.240***	0.310***	0.179***	0.010***	0.018***	0.019***	−0.005	−0.019
CPI	0.000***	0.000***	0.000**	0.000***	0.000	0.003***	0.002***	0.002*	0.001	−0.002	0.000	0.000	0.001*	0.000	0.000
EXG	0.000	0.001	0.001	0.004***	0.002**	0.004	−0.011	−0.010	0.041**	0.077***	−0.017***	−0.020***	−0.022***	−0.010*	−0.003
IND	0.003	0.008**	0.018***	0.033***	0.024	−0.287*	−0.024	0.483***	0.959***	1.407***	0.044	0.080**	0.077**	−0.079*	−0.174**
INF	0.000	−0.005	−0.001	−0.002	−0.003	−0.184	0.060	−0.142	0.080	0.687	0.030	0.019	0.143	0.183*	0.293**
TRD	−0.014***	−0.008***	−0.007***	−0.016***	−0.014*	0.452***	0.358***	0.421***	0.271***	0.299***	−0.051***	−0.073***	−0.092***	−0.043	−0.040
UMP	−0.001***	0.000	0.001**	0.000	−0.001	0.020***	0.021***	0.015**	0.006	−0.025**	0.000	0.005**	0.015***	0.008***	0.003
MAN	0.091***	0.109***	0.123***	0.195***	0.132**	3.881***	3.888***	1.367***	0.224	−5.165***	0.682***	0.636***	0.633***	0.217	0.016
Pseudo R^2	0.122	0.135	0.111	0.160	0.270	0.445	0.520	0.574	0.582	0.577	0.246	0.288	0.315	0.317	0.268
	Fish					Forest					Graze				
C	0.144	0.307***	0.102	1.095	3.755***	0.480**	0.742**	1.089**	−1.405*	0.343	−0.441**	−0.868***	−1.311***	−0.720	−1.684
REV	0.005***	0.009***	0.003	−0.024***	−0.065***	−0.002	−0.016**	−0.037***	−0.063***	−0.136***	−0.009**	−0.003	−0.010**	−0.012	−0.064***
ECO	0.000**	0.001**	0.002**	0.002	0.005**	0.002	0.004*	0.004	0.014***	0.004	0.002*	0.002*	0.004***	0.002	0.008
FIN	0.000	0.000	0.002**	0.002	0.001	−0.002	−0.006***	−0.015***	−0.023***	−0.016*	0.001	0.000	−0.003	−0.008**	−0.005
POL	0.000	0.000	0.002***	0.003***	0.003*	−0.001	0.000	0.007***	0.011***	0.009***	0.000	0.002***	0.003***	0.005*	−0.008**
GDP	−0.047**	−0.120***	−0.072	−0.415*	−1.004***	−0.088	−0.121	−0.078	0.694***	0.619	0.163***	0.258***	0.443***	0.382**	0.918**
GDP^2	0.004**	0.008***	0.005	0.028**	0.066***	0.008**	0.011*	0.010	−0.030**	−0.020	−0.007**	−0.012***	−0.022***	−0.019**	−0.041*
CPI	0.000***	0.000***	0.000	0.000	0.000	0.000	0.000	0.001***	0.000	0.001	0.000***	−0.001***	0.000*	−0.001*	−0.004***
EXG	0.001	0.002***	0.007***	0.009**	0.000	−0.010***	−0.007***	−0.008	0.001	−0.012	−0.006**	0.000	0.001	0.004	0.005
IND	−0.020***	−0.014**	−0.030*	0.235***	0.480***	−0.034	−0.014	−0.057	−0.170	−0.157	−0.052***	−0.068***	−0.113***	−0.093	0.102
INF	0.000	0.009	0.046*	−0.023	−0.143**	−0.060	0.017	0.037	−0.011	−0.060	0.018	0.007	−0.015	−0.076	−0.301
TRD	0.006	0.029***	0.021***	0.066***	0.000	−0.012	−0.001	−0.016	0.082*	0.019	0.019***	0.013***	0.004	−0.017	−0.064**
UMP	0.000	−0.001	−0.003***	−0.008***	−0.012***	0.002	0.002	−0.003	−0.013***	−0.018**	−0.003***	−0.005***	−0.008***	−0.007**	−0.013
MAN	−0.056**	−0.020	0.147	−0.115	−1.083***	0.587***	0.603***	0.250	−1.073***	−0.606	−0.644***	−0.912***	−1.108***	−1.378***	−3.822
Pseudo R^2	0.107	0.115	0.109	0.177	0.299	0.140	0.145	0.176	0.252	0.317	0.226	0.226	0.207	0.171	0.242

Notes: This table reports the estimation results of international tourism revenue and country risk impact on ecological footprint according to Eq. (1). Standard errors are bootstrapped replications. *, **, and *** represent significance at the 10%, 5%, and 1% levels, respectively. The variable definitions same as the notes in Table 1.

Table 4
Estimates of the QR-based tourism development-induced EKC hypothesis on models (Eq. (2)).

Variable	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90
	Built					Carbon					Crop				
C	−0.110	−0.377**	0.157	−0.236	0.150	18.642***	18.901***	14.814***	21.415***	8.655	2.075**	2.221**	2.235*	0.886	0.583
ECO	0.000	0.000	0.000	−0.001**	−0.002***	−0.004	−0.004	−0.007	0.015**	0.012	−0.001	0.002	0.001	−0.002	0.000
FIN	0.000	0.000***	−0.001**	0.000	0.000	0.002	0.003	0.009	−0.009	−0.003	−0.005***	−0.009***	−0.006**	−0.004	−0.005
POL	0.000	0.000	0.000	0.001***	0.001	0.012***	0.020***	0.014***	−0.013**	−0.004	−0.001	−0.001	−0.001	0.000	0.005***
GDP	0.003	0.006***	0.006***	0.015***	0.029***	0.586***	0.716***	0.915***	1.088***	1.146***	0.069***	0.080***	0.127***	0.139***	0.158***
REV	0.012	0.035**	−0.019	0.012	−0.018	−2.350***	−2.404***	−2.149***	−2.858***	−1.840***	−0.212**	−0.241**	−0.255**	−0.119	−0.093
REV^2	0.000	−0.001***	0.000	0.000	0.000	0.057***	0.056***	0.050***	0.069***	0.046***	0.005**	0.006**	0.006**	0.003	0.002
CPI	0.000***	0.000**	0.000*	0.000***	0.000**	0.002	0.002**	0.000	−0.003**	−0.005***	0.000	0.000	0.000	0.000	0.000
EXG	0.000	0.002***	0.001*	0.004***	0.001	−0.005	−0.004	0.035**	0.085***	0.089***	−0.016***	−0.020***	−0.021***	−0.010**	−0.001
IND	0.000	0.008***	0.015***	0.026***	0.002	−0.162	−0.249	0.078	0.453*	1.126**	0.006	0.037	0.020	−0.044	−0.086
INF	−0.006	−0.008	−0.001	−0.001	−0.002	0.068	0.031	−0.081	−0.337	−0.007	0.030	0.006	0.136	0.202*	0.319
TRD	−0.013***	−0.009***	−0.007***	−0.015***	−0.013*	0.333***	0.278***	0.402***	0.436***	0.410***	−0.047***	−0.056***	−0.095***	−0.046	−0.072
UMP	−0.001***	0.000**	0.001**	0.000	−0.001**	0.028***	0.012**	0.002	−0.026***	−0.036***	0.000	0.005**	0.011***	0.010***	0.006*
MAN	0.087***	0.089***	0.112***	0.185***	0.104**	3.005***	3.183***	1.123*	−2.453***	−7.205***	0.746***	0.675***	0.480**	0.228	0.208
Pseudo R^2	0.118	0.136	0.111	0.158	0.254	0.448	0.495	0.543	0.547	0.566	0.243	0.282	0.312	0.318	0.266
	Fish					Forest					Graz				
C	−0.142	−0.023	−1.255***	−3.595***	−6.273***	0.665	2.352**	2.631*	2.353	6.483	−1.049**	−1.212***	−2.085***	−0.597	0.514
ECO	0.000	0.002***	0.003***	0.002	0.006***	0.002	0.003*	0.006**	0.007	0.007	0.002**	0.002*	0.002*	0.003	0.005
FIN	0.000	0.000	0.002**	0.002	0.002	−0.001	−0.004***	−0.015***	−0.017***	−0.013	0.001	−0.001	−0.004**	−0.006*	−0.002
POL	0.000	0.000	0.002***	0.003***	0.004**	−0.002	0.000	0.007***	0.010***	0.010***	0.000	0.001	0.002**	0.004	−0.011***
GDP	0.013***	0.013***	0.011**	0.075***	0.145***	0.061***	0.084***	0.098***	0.176***	0.245***	0.043***	0.047***	0.044***	0.036	0.223***
REV	0.010	−0.007	0.100**	0.245***	0.451***	−0.071	−0.252**	−0.247*	−0.243	−0.566	0.090*	0.111***	0.215***	0.108	−0.019
REV^2	0.000	0.000	−0.002	−0.007***	−0.012***	0.002	0.005**	0.005	0.004	0.010	−0.002**	−0.003***	−0.005***	−0.003	−0.001
CPI	0.000***	0.000**	0.000**	0.000	−0.001***	−0.001*	0.000	0.001**	0.000	0.002**	0.000**	0.000**	0.000**	−0.001***	−0.004***
EXG	0.001	0.001	0.006**	0.018***	0.010*	−0.012***	−0.008***	−0.007	−0.001	−0.001	−0.006***	−0.002	0.001	0.002	−0.001
IND	−0.029***	−0.034***	−0.039	0.185***	0.383***	−0.051**	−0.028	−0.078	−0.030	−0.260*	−0.031**	−0.041***	−0.063***	−0.077	0.262**
INF	−0.001	0.007	0.045***	−0.014	−0.106	−0.115	0.003	0.062	−0.020	−0.040	0.024	0.013	−0.008	−0.074	−0.330
TRD	0.010	0.031***	0.022***	0.043*	0.000	−0.022	0.001	−0.009	0.045	0.080	0.018***	0.015***	0.009	−0.026**	−0.094***
UMP	−0.001***	−0.002***	−0.005	−0.011***	−0.019***	0.001	0.003**	−0.004	−0.010**	−0.007	−0.002***	−0.003***	−0.005***	−0.006*	−0.010
MAN	−0.089***	−0.077**	0.078	−0.162	−1.524***	0.644***	0.679***	0.027	−0.763**	−0.460	−0.603***	−0.735***	−1.042***	−1.371***	−3.309***
Pseudo R^2	0.103	0.103	0.110	0.179	0.281	0.140	0.145	0.177	0.245	0.315	0.225	0.215	0.192	0.166	0.236

Notes: This table reports the estimation results of international tourism revenue and country risk impacts on the ecological footprint according to Eq. (2). The same as the notes in Tables 1 and 3 improving more environmentally protection policies (Kaufmann et al., 1998) to encouraging EF-consuming lifestyles (Shafik, 1994) for carbon, crop, and fishing footprints. This indicates GDP growth, while tending at first to raise EF in order to supply the needed goods and services in the economy (Cropper and Griffiths, 1994), ultimately forces EF to drop via improved environmental conservation as the economy grows (Seldon and Song, 1994) for carbon, crop, and fishing footprints. GDP shows U-shape and inverted U-shape impacts for different footprints and different quantiles. These results specify that heterogeneity does exist in different EF components. Moreover, REV show an asymmetric effect on fish footprint, indicating low fish EF countries consume more fish, until their REV reaches a threshold. ECO and POL (FIN) show largely significantly positive (negative) impacts on EF, revealing that country risk ratings have different impacts on EF. Likewise, the non-linear GDP and EF findings vary from prior studies where linear functional forms are assumed, which may be a misspecification. Our findings illustrate that the GDP-EF nexus is different across different EF components.

4.4.2. Further evidence for the subgroup of low-country risk rating countries

To measure how different levels of CR influence the EKC hypothesis, we replicate the examination with a low country risk rating subgroup sample (i.e., we use composite country risk ratings divided into high- and low-risk countries) instead of the full sample. In this regard, Table 7 summarizes the results of the low-CR (high-risk) subgroups. Comparing the non-linear GDP impact on EF in Table 3 for the full sample, we obtain slightly more sign-consistent results across quantiles than those of the full sample. Inverted U-shape relationships exist at the 10th built-up, 90th fish, and 25th, 75th, and 90th graze quantiles, whereas U-shape relationships exist in carbon, crop, forest, and lower quantiles of fish footprints. The results imply that, for high-risk countries, GDP growth moves from enhancing more environmentally protection policies (Kaufmann et al., 1998) to encouraging EF-consuming lifestyles (Shafik, 1994) for carbon, crop, forest, and fishing footprints. These results specify that heterogeneity does exist in different EF components. Moreover, higher-risk countries tend to make less carbon, crop, and fishing footprints until their GDP reaches a threshold. CR of a high-risk country shows less significant impacts on EF than that of the full sample. Our findings illustrate that high-risk countries tend to have U-shape relationships between EF and GDP.

4.4.3. Subsample of the non-financial crisis period

Tienhaara (2010) states that the relationship between financial and environmental crises delivers both opportunities and threats to achieving long-term economic and ecological sustainabilities. Therefore, according to Hill et al. (2015) and Johnson et al. (2000), we set the global financial crisis period at 2008–2009 and Asian financial crisis period at 1997–1998. Thus, we remove the effect of the 2008-2009 global financial crisis and 1997-1998 Asian financial crisis as non-financial crisis sub-periods to run QR models in Table 8. Just like in the full sample, we find that the non-financial crises' results do not support the claim that an inverted U-shape relationship between GDP and footprint exists, but our findings show a U-shape relationship. During non-financial crisis periods, a U-shape relationship implies that GDP changes have moved from enhancing more environmentally friendly policies to encountering EF increases; in the later stages of increasing GDP, EF also increases. Therefore, we confirm that the GDP-EF nexus is non-linear during non-financial crisis periods.

4.4.4. Subsample of developing countries

Developing countries show optimism toward capitalizing on the synergies between the environment and tourism in order to follow the 'green growth' agenda for preservation of natural resources (Zaman et al., 2016). Therefore, we run the subsample of 97 developing countries in Table 9. We also find the non-linear GDP impact on EF in Table 3 for the full sample. Inverted U-shape relationships exist in 10th built-up land quantile, 90th fish footprint quantile, and 25th-90th grazing footprint quantiles, whereas U-shape relationships exist in most of quantiles of carbon and crop footprints. The results imply for developing countries that heterogeneity does exist in different EF components, and there is an asymmetric relationship between fishing footprint and GDP. Non-linear relationships exist between GDP and EF. We discover no other notable variances between the main findings and tests on developing countries.

4.4.5. Subsample of European countries

According to International Tourism Highlights (2019) from the World Tourism Organization, Europe accounts for half of the world's international arrivals and represents nearly 40% of international tourism receipts, followed by Asia and the Pacific.[3] Because the association between tourism revenue and GDP varies with geographic areas (Çağlayan et al., 2012), we use the largest sample area, 38 European countries, as a subgroup to test the robustness of CR indices for specific region samples in Table 10. The findings do support the claim that inverted U-shape relationships exist between economic development and carbon, crop, forest, as well as the 10th quantile of fish footprints, whereas our results support a U-shape relationship between the 90th grazing land quantile, the 75th-90th quantiles of fishing, as well as the 10th quantiles of built-up land. We observe a greater inverted U-shape relationship between EF and GDP in European countries. The results imply for European countries that heterogeneity does exist in different EF components, and there is an asymmetric relationship between built-up land as well as fishing footprints and GDP. Non-linear relationships between GDP and EF are supported. Consistent with the results in Table 3, REV tends to decrease forest and graze footprints.

The European findings generally indicate that as GDP grows, it first tends to raise EF in order to supply the needed goods and services in the economy (Cropper and Griffiths, 1994), but eventually forces EF to drop through increased environmental conservation as the economy grows (Seldon and Song, 1994). The EF consumption exhibits obvious geographical features. We summarize our findings in Table A3 and observe that the inverted U-shape relationship is supported in some EF quantiles.

4.5. Implication and discussion

Environmental degradation has gradually worsened with the progress of economic development, but given rise to a strand of the literature on sustainable development. Such research is imperative in that it points out the ecological footprints that might convey tourism growth and country risk ratings.

Our results support a number of specific implications. First, according to the positive determinant role of political risk rating on ecological footprint quantiles, policy makers should thoroughly consider institutional or governmental policies regarding the footprints before policy implementation. Moreover, due to the U-shape impact of political risk ratings on fishing ground, forest, and carbon, policy makers should be aware of the degradation on these

[3] Data source: International tourism highlights, 2019 edition from World Tourism Organization. https://www.e-unwto.org/doi/pdf/10.18111/9789284421152.

Table 5
Estimates of the QR-based country risk-induced EKC hypothesis on ecological footprint models (Eq (3)).

Variable	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90
Built						Carbon					Crop				
C	−0.003	−0.031	−0.094	−0.151*	−0.125	−1.331	−1.328	−0.550	−2.174	−9.081***	0.238	0.031	−0.028	−0.821	−1.489*
REV	−0.001	−0.004***	−0.003**	−0.007***	−0.009***	0.039	0.013	−0.018	0.006	−0.030	0.020***	0.021***	0.013*	0.006	−0.011
GDP	0.003	0.007***	0.007***	0.017***	0.031***	0.547***	0.720***	0.877***	1.104***	1.180***	0.067***	0.073***	0.118***	0.150***	0.165***
ECO	0.001	0.002*	0.003*	0.003	0.007**	0.011	−0.044	−0.052	−0.121*	−0.126**	−0.021*	−0.042***	−0.026**	0.008	0.020
ECO^2	0.000	0.000**	0.000*	0.000*	0.000***	0.000	0.001	0.001	0.002**	0.002**	0.000*	0.001***	0.000**	0.000	0.000
FIN	0.001	0.002	0.004	0.004	−0.002	−0.091	−0.103	−0.199***	−0.045	0.121	−0.019*	0.014	0.005	−0.003	0.014
FIN^2	0.000	0.000*	0.000	0.000	0.000	0.001	0.001	0.003***	0.000	−0.002	0.000	0.000	0.000	0.000	0.000
POL	−0.001	−0.001	−0.002*	0.000	0.002	−0.085**	−0.069*	−0.034	−0.108**	−0.046	0.001	−0.009	−0.011	0.009	0.020
POL^2	0.000	0.000	0.000**	0.000	0.000	0.001**	0.001**	0.000	0.001**	0.000	0.000	0.000	0.000	0.000	0.000
CPI	0.000***	0.000*	0.000**	0.000***	0.000***	0.004**	0.002**	0.001	−0.001	−0.003*	0.000	0.000	0.000	0.000	0.000
EXG	0.000	0.001***	0.002*	0.003***	0.000	−0.008	−0.010	0.048**	0.067***	0.101***	−0.019***	−0.023***	−0.022***	−0.012**	0.000
IND	0.003	0.011***	0.023***	0.029***	0.003	−0.176	−0.148	−0.204	0.371	1.437***	−0.002	0.063*	0.027	−0.059	−0.091*
INF	−0.002	−0.005	0.000	−0.001	0.003	−0.094	0.022	−0.108	−0.394	−0.049	0.031	0.024	0.032	0.197	0.387**
TRD	−0.012***	−0.008***	−0.004	−0.014***	−0.019***	0.360***	0.390***	0.403***	0.281***	0.312***	−0.064***	−0.080***	−0.094***	−0.044	−0.063
UMP	−0.001***	−0.001***	0.000	−0.001*	−0.002***	0.017***	0.009	−0.002	−0.032***	−0.048***	−0.001	0.003	0.012***	0.008***	0.004
MAN	0.070***	0.092***	0.120***	0.178***	0.123***	3.712***	2.771***	1.515**	−1.810*	−8.692***	0.702***	0.522***	0.557***	0.189	0.134
Pseudo R^2	0.117	0.139	0.119	0.163	0.266	0.417	0.485	0.540	0.543	0.562	0.247	0.290	0.312	0.319	0.273
Fish						Forest					Graze				
C	−0.033	0.064	0.214	0.875	2.685	0.545**	0.633**	−0.148	−1.063	1.086	−0.192	−0.757***	−0.772***	−0.354	1.466
REV	0.005***	0.007***	0.005*	−0.024***	−0.050***	−0.002	−0.026***	−0.040***	−0.068***	−0.139***	−0.006**	−0.002	0.000	−0.010	−0.081***
GDP	0.012***	0.012***	0.006	0.045***	0.052**	0.044***	0.085***	0.088***	0.147***	0.257***	0.043***	0.049***	0.048***	0.054**	0.210***
ECO	−0.004	−0.003	−0.001	−0.050	−0.119*	0.003	0.006	0.025*	0.053**	0.050	−0.007*	−0.002	0.005	0.031**	0.057*
ECO^2	0.000	0.000**	0.000	0.001	0.002**	0.000	0.000	0.000	−0.001**	−0.001	0.000**	0.000	0.000	0.000**	−0.001*
FIN	0.003	0.001	−0.012	−0.007	0.018	−0.005	0.012	0.061**	0.098***	−0.022	0.005	0.019***	0.020	0.016	−0.048
FIN^2	0.000	0.000	0.000*	0.000	0.000	0.000	0.000	−0.001***	−0.002***	0.000	0.000	0.000***	0.000	0.000	0.001
POL	−0.002	−0.005***	−0.004	−0.014	−0.046*	−0.023***	−0.035***	−0.038***	−0.027	0.011	0.007**	0.013***	0.014***	0.003	−0.017
POL^2	0.000	0.000***	0.000	0.000	0.000**	0.000***	0.000***	0.000***	0.000**	0.000	0.000**	0.000***	0.000**	0.000	0.000
CPI	0.000***	0.000***	0.000	0.000	−0.001**	0.000	0.000**	0.001***	0.000	0.002	0.000**	−0.001***	−0.001*	−0.001**	−0.004***
EXG	0.000	0.001	0.005**	0.010**	0.001	−0.009***	−0.014***	−0.011**	−0.002	−0.007	−0.004*	−0.002	0.001	0.002	0.003
IND	−0.024***	−0.032***	−0.032**	0.195***	0.392***	−0.001	0.041	0.047	−0.021	−0.172	−0.045***	−0.027	−0.066**	−0.040	0.224**
INF	−0.001	−0.005	0.028	−0.021	−0.122	−0.034	−0.045	0.110	0.035	−0.049	0.032	0.017	0.024	−0.090	−0.333
TRD	0.005	0.025***	0.016**	0.032	0.005	−0.009	−0.018	0.003	0.086**	0.075	0.017***	0.017***	0.010	−0.005	−0.071*
UMP	−0.001***	−0.002***	−0.003***	−0.009***	−0.010***	0.001	0.002	−0.005*	−0.007*	−0.014*	−0.002***	−0.003***	−0.005***	−0.006	−0.009*
MAN	−0.080***	−0.066**	0.082	−0.231	−1.243***	0.567***	0.715***	−0.040	−0.567*	−0.554	−0.526***	−0.840***	−1.136***	−1.467***	−3.294***
Pseudo R^2	0.106	0.111	0.112	0.178	0.300	0.155	0.160	0.202	0.269	0.315	0.228	0.223	0.196	0.170	0.239

Notes: This table reports the estimation results of international tourism revenue and country risk impacts on the ecological footprint according to Eq. (3). The same as the notes in Tables 1 and 3 footprints when setting policies. Second, international tourism revenues benefit (determent) to countries with higher (lower) EF quantiles. Policy makers of countries with lower EF quantiles should be aware of the harmful effect of tourism revenues on their environmental degradation. Third, our finding suggests that carbon-absorption land is the largest category among ecological footprints. GDP, REV, and CR have U-shape effects on carbon footprint. Therefore, high GDP, high REV, and low economic risk countries should enhance environmental quality control when strengthening tourism and economic development.

Fourth, from the results of quantile regressions, we confirm U-shape relations for carbon-absorption land, followed by cropland. This implies that the costs of country risk ratings improvement, economic growth, and tourism development are consumptions of carbon-absorption and cropland, therefore it is important to call for a sustainable economic development to be achieved. Our findings are consistent with Cervelló-Royo et al. (2016), presenting a strong association between environmental awareness, country risk rating, and tourism activity. Therefore, quantile regression offers a comprehensive relationship of variables across different EF quantiles.

Fifth, non-linear and asymmetric relationships appear between EF, CR, international tourism revenues (REV), and GDP, which allow for more detailed policy making for countries under different EF conditions. Likewise, Lantz and Feng (2006) find that previous studies may have misspecified the application of a linear relation between CO_2 emission and GDP variables. Therefore, a policy solution can be devised based on the different levels of quantiles, and the solution can be designed in a phase-wise manner.

Finally, the most vital implication of our results is that uniform environmental quality control policies are unlikely to succeed correspondingly across countries with dissimilar ecological footprint levels and across dissimilar ecological footprint components. Our paper identifies an expanding channel through which improvements in a country risk rating might sway environmental degradation, and thus governments in countries with economic development should strive to put in place a sound eco-environment. Tourism industry development should not come at the cost of environment degradation, and hence policy makers should move to develop ecotourism policies. Romuald (2011) claims that many environmental issues can be illuminated by bad government and institutional failure. Dasgupta and De Cian (2018) show that the effects of environmental interventions depend on the political environment that leads to a policy choice. The overall policy implications are a wakeup call for environmentalists and government officials to protect the natural flora of the world.

5. Conclusion

Two weaknesses in the existing literature arise. First, most studies have employed total ecological footprint when investigating the EKC hypothesis, which denotes only a rough score of environmental degradation and cannot identify what element should be paid more attention. Second, scant research explores the three subcomponents of country risk rating-induced EKC hypothesis, where a government's policy setting greatly influences environmental quality. Therefore, to fully understand the validity of the EKC hypothesis with more reliable environment indicators, we utilize six ecological footprints as dependent variables and tourism development, per capita real income, and country risk ratings as independent variables by using panel data of 123 countries for the period 1992–2016. For an empirical pursuit, we use the quantile regression approach that facilitates the effects over different conditional distributions of the ecological footprints and search for possible non-linear and/or asymmetric relationships between variables. In other words, we validate the inverted U-shape income EKC, tourism ECK, and country risk rating EKC hypotheses.

Using quantile regression to consider a full range of conditional quantile functions, our results specify that the effects of various factors on different ecological footprint components and different ecological footprint distributions are distinctly heterogeneous, signifying the need for analysis considering the heterogeneities across different EF quantiles and the different features of EF subcomponents in the tourism-, economic-, and country risk-induced EKC estimations. In particular, international tourism revenues decrease (increase) ecological footprints in countries with higher (lower) fishing footprint quintiles, signifying the asymmetric effect between fish footprint and tourism across different EF quantiles. We also find that among the country risk ratings, political risk rating has a more positive impact on ecological footprint than those of economic and financial risk ratings, and that political risk ratings do impede a country's eco-environmental quality.

Along similar lines, Magnani (2001) pinpoints that GDP is not the single factor that governs the negative downward-sloping EKC. Consequently, it is essential to probe other factors that have possible associations with the EKC hypothesis across countries. Our results support an inverted U-shape relationship exists between income and grazing land for all quantiles and forest at higher quantile; tourism and fish footprints at intermediate and higher quantiles, built-up land at lower quantiles, grazing at lower and intermediate quantiles; ECO, forest, and grazing footprints at higher quantiles; and FIN and forest footprint at intermediate and higher quantiles. This suggests that GDP, tourism, economic risk rating, and financial risk rating growth, while tending at first to raise EF in order to supply the needed goods and services in the economy, ultimately force EF to decrease through improved environmental conservation as the economy grows for fish, forest, and grazing footprints. Moreover, several ecological footprint components for European countries support the EKC hypothesis, indicating that the geographic effect exists in the hypothesis. However, the findings of the sample, developing countries, non-financial crisis period, and low country risk rating countries generally clarify that U-shape associations persist between GDP, tourism, and country risk ratings and ecological footprints. Therefore, the effectiveness of economic development policies requires a complete eco-environmental policy to sustain long-run growth in all the six subcomponents of EF.

From the findings of this study, it is suggested that governments could consider reducing the ecological footprint arising from economic, tourism, and country risk policy settings, particular for low ecological footprint countries. Additionally, our findings indicate that tourism can increase or decrease the use of ecological footprints. Thus, it is important for participants in the tourism industry to develop sustainable tourism. Moreover, suggestions for subcomponent measures of ecological footprints and country risk ratings are important, because of the different features of ecological footprints and country risk ratings as shown in our results. It is vital for scholars to conduct country risk or ecological footprint analyses in order to employ the subcomponents for strengthen their findings.

Instead of focusing attention on specific institutional factors, we broaden the range of investigation by exploring the subcomponents of country risk (i.e., economic risk, financial risk, and political risk), tourism, and GDP on the six components of EF, so as to gain more comprehensive insight on the international evidence in the related literature. This study is limited by not accounting for an N-shape relationship as well as the thresholds of U- and inverted U-shape EKC hypotheses, because these issues are not our focal points. We recommend that future studies investigate the thresholds and N-shape relations so as to provide a better understanding

Table 6
Estimates of the QR-based economic-induced EKC hypothesis on ecological footprint models for high-international tourism revenue countries.

Variable	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90
Built						Carbon					Crop				
C	0.209	0.334***	0.404	1.083**	1.788***	−24.926***	−35.970***	−26.213**	−33.164***	−27.742***	−0.784	−2.474**	−2.153*	−3.426***	−1.361
REV	0.000	−0.006	−0.013	−0.006	−0.002	0.075	0.097	0.187	0.471***	0.418***	−0.011	0.015	−0.007	−0.044	−0.058
ECO	0.000	0.000	0.000	0.000	−0.001	−0.004	−0.001	0.014	0.023*	0.023**	0.004	0.010**	0.012***	0.005	0.011**
FIN	−0.001	−0.001***	−0.001**	0.000	0.001	0.008	0.007	0.001	0.007	−0.001	−0.005	−0.007**	−0.008*	0.002	0.005
POL	0.001	0.001***	0.001***	0.000	0.000	0.013*	0.013	0.021**	0.031***	0.033***	−0.001	0.000	0.001	0.001	0.001
GDP	−0.068*	−0.061**	−0.042	−0.224**	−0.410***	3.177**	5.288**	2.562	2.130	0.794	0.283	0.545***	0.658**	1.288***	0.999
GDP^2	0.004*	0.003**	0.002	0.013***	0.024***	−0.106	−0.211*	−0.079	−0.056	0.019	−0.014	−0.028***	−0.034**	−0.066***	−0.051
CPI	0.000	0.000***	0.000**	0.000*	0.000	0.000	−0.001	−0.004	−0.009**	−0.008***	0.000	0.000	0.000	−0.001	−0.002
EXG	−0.001	0.000	−0.002*	−0.003	−0.001	0.053**	0.080**	0.127**	0.323***	0.310***	−0.040**	−0.023***	−0.025***	−0.018**	−0.027**
IND	0.022	0.008	0.008	−0.001	−0.006	0.927***	0.925**	1.646***	2.650***	3.331***	0.045	−0.006	−0.092	−0.322***	−0.411***
INF	−0.005	0.019	0.005	−0.008	−0.003	0.704	0.667	0.826	1.760***	1.971***	0.082	0.188	0.211	0.076	−0.004
TRD	−0.018***	−0.011***	−0.012***	−0.007	0.015	0.390***	0.435***	0.602***	0.810***	0.805***	−0.085***	−0.078***	−0.072***	−0.088*	−0.085
UMP	0.000	0.001***	0.001	0.001	0.002	0.030***	0.029	0.044	0.043**	0.034	0.019*	0.022***	0.018***	0.004	−0.003
MAN	0.150***	0.109***	0.172***	0.159*	0.148	−1.533	−0.809	−5.995***	−15.686***	−17.192***	0.954*	0.343	0.172	−0.215	−0.629
Pseudo R^2	0.214	0.231	0.134	0.138	0.372	0.611	0.590	0.523	0.534	0.595	0.253	0.290	0.324	0.334	0.353
Fish						Forest					Graze				
C	−1.268**	−1.180	−1.104	−1.328	0.568	−1.073	2.161	6.748**	5.931	6.307	0.053	−0.031	0.537	1.376	3.449**
REV	0.013	0.031**	0.011	−0.061**	−0.077	−0.042	−0.112***	−0.184***	−0.178***	−0.228***	0.002	−0.020	−0.034	−0.003	0.036
ECO	0.003	−0.001	−0.002	−0.002	−0.001	0.005**	0.009***	0.021***	0.017*	0.016*	0.001	0.001	0.003*	−0.001	−0.007
FIN	0.001	0.001	0.004**	0.003**	0.006***	−0.005	−0.010*	−0.027***	−0.012	−0.002	0.000	−0.001	−0.006	−0.017***	−0.024***
POL	0.000	0.000	0.001	0.002	0.001	0.007**	0.009***	0.014***	0.005	0.001	−0.001	−0.001	0.001	0.000	−0.002
GDP	0.172*	−0.001**	0.068	0.528**	0.216	0.477	0.115	−0.585	−0.839	−0.662	−0.004	0.174	0.124	−0.172	−0.931**
GDP^2	−0.008*	0.003***	0.001	−0.025**	−0.007	−0.026	−0.007	0.031	0.056	0.051	0.003	−0.006	−0.003	0.017	0.062***
CPI	0.000	−0.001*	−0.001	0.002**	0.002*	0.002**	0.004***	0.007***	0.007***	0.006***	−0.001**	−0.001	0.000	−0.002**	−0.004***
EXG	0.015**	0.027	0.032***	0.010*	0.007	−0.035***	−0.045***	−0.067***	−0.068***	−0.068***	0.001	−0.004	−0.004	0.000	0.001
IND	−0.009	0.049***	−0.001	−0.084	−0.200**	−0.149***	−0.187***	−0.171	0.210	0.111	−0.010	−0.055	−0.061	0.142	0.471***
INF	0.083	0.027	0.026	−0.013	0.044	0.066	0.069	0.344	0.164	0.108	0.023	−0.007	0.032	−0.370**	−0.468**
TRD	0.026	0.029***	−0.001	−0.033**	0.052	−0.045*	−0.052***	−0.103**	−0.183***	−0.244***	0.030***	0.012	−0.006	0.014	0.015
UMP	−0.001	0.001	−0.004	−0.016***	−0.014***	−0.004	0.005	−0.001	−0.004	−0.007	−0.002	−0.007***	−0.011***	−0.016***	−0.011
MAN	0.144	0.360**	0.816***	1.374***	1.677***	0.417	0.653**	0.856	0.838	1.360*	−0.441***	−0.657***	−0.700**	−1.879***	−2.560***
Pseudo R^2	0.166	0.252	0.367	0.456	0.398	0.198	0.237	0.310	0.404	0.478	0.298	0.290	0.309	0.382	0.499

Notes: This table reports the estimation results of 34 high international tourism revenue countries for period t according to Eq. (1). We split our data into two (high and low) sub-groups according to total ecological footprints.. The same as the notes in Tables 1 and 3

Table 7
Estimates of the QR-based economic-induced EKC hypothesis on ecological footprint models for low country risk rating countries.

Variable	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90
Built						Carbon					Crop				
C	−0.199**	0.012	0.097	0.221	0.338	6.139**	10.114***	9.607***	16.947**	34.293***	2.710***	3.909***	3.174***	3.979***	8.889**
REV	−0.002	−0.008***	−0.010***	−0.009***	−0.008***	0.015	0.026	0.034*	0.042	0.039	0.023***	0.023**	0.039***	0.006	−0.040*
ECO	0.000	0.000	0.000	0.000	0.000	−0.022***	−0.017*	−0.008	0.002	0.002	−0.001	−0.001	−0.003	−0.004	−0.003
FIN	0.000	0.000	0.000	−0.001	−0.001	0.004	0.016**	0.019**	0.011	0.024***	−0.002	−0.001	0.001	0.002	0.000
POL	0.000	0.000	0.000	0.001**	0.001***	0.006	0.010*	0.014**	0.010*	0.014***	0.003**	0.001	0.004**	0.004***	0.006**
GDP	0.056***	0.026	0.005	−0.063	−0.100	−2.178***	−3.381***	−3.125***	−4.995**	−9.627***	−0.850***	−1.105***	−1.026***	−1.043**	−2.168**
GDP^2	−0.003***	−0.001	0.001	0.005	0.007	0.150***	0.230***	0.220***	0.358**	0.671***	0.059***	0.074***	0.069***	0.076***	0.149***
CPI	0.000**	0.000	0.000	0.000***	0.000**	0.000	0.001	0.002	0.002	−0.001	0.000	0.000	0.000	0.000	0.002**
EXG	0.000	0.002**	0.004***	0.004***	0.002***	0.000	−0.011	−0.022**	−0.037*	−0.022	−0.016***	−0.022***	−0.009	−0.003	−0.004
IND	0.015**	0.005	0.016	0.041***	0.053***	0.382**	0.093	−0.305***	−0.493**	−0.627***	0.011	−0.015	−0.077	−0.166***	−0.062
INF	−0.010	−0.001	−0.001	−0.005	−0.010	0.022	0.091	0.065	0.194	0.195	0.041	0.039	0.205	0.208*	0.403**
TRD	−0.007	−0.008*	−0.012*	−0.013	−0.018*	0.073	0.384***	0.440***	0.381***	0.447***	0.085**	0.107***	0.220***	0.206***	0.128
UMP	−0.001*	−0.001	0.000	−0.001**	−0.001***	0.010	0.021**	0.025***	0.015	0.003	0.001	0.003	0.011***	0.004*	0.001
MAN	0.149***	0.164***	0.168***	0.196***	0.196***	3.032***	3.952***	2.939***	1.723*	0.158	0.599**	0.722***	0.621**	0.575**	0.359
Pseudo R^2	0.196	0.178	0.261	0.397	0.462	0.324	0.356	0.431	0.503	0.625	0.291	0.299	0.395	0.475	0.430
Fish						Forest					Graze				
C	0.193	0.205*	−0.378	−1.498*	−3.858***	1.151**	2.325***	2.760**	0.700	4.095**	−0.110	−0.607	−0.816	−1.616	−7.372
REV	0.004***	0.004**	0.012***	0.020*	0.035***	0.002	−0.005	−0.013	0.001	−0.082***	−0.011**	−0.012**	−0.039	−0.187***	−0.239***
ECO	0.000	0.000	0.000	−0.001	−0.001	−0.002	−0.001	0.007*	0.005	−0.002	0.002	0.002	0.003	0.003	0.018*
FIN	0.000	0.000	0.001	0.002	0.004*	−0.002*	−0.001	−0.003	−0.005	−0.003	−0.002	−0.002	−0.010**	−0.004	−0.004
POL	0.000	0.000	0.000	0.001	−0.003	−0.002**	0.000	0.001	0.005*	0.005*	0.002***	0.003***	0.004	0.005	−0.004
GDP	−0.062*	−0.075**	0.014	0.187	0.866***	−0.416***	−0.723***	−0.848***	−0.324	−0.865*	0.091	0.232**	0.507	1.599***	3.538***
GDP^2	0.004*	0.005***	−0.001	−0.013	−0.059***	0.030***	0.051***	0.061***	0.028	0.067**	−0.001	−0.009	−0.022	−0.077**	−0.205**
CPI	0.000**	0.000*	0.000	0.000	0.000	0.000	0.000	−0.001	0.000	0.000	0.000**	0.000**	−0.001	0.000	0.000
EXG	0.001	0.002*	−0.001	0.005	−0.008	−0.013***	−0.007	−0.007	−0.016*	−0.008	0.001	0.006	0.016	0.025**	−0.030
IND	−0.024**	−0.005	0.053*	0.163***	0.123**	0.211***	0.240***	0.211*	0.174	0.300**	−0.056***	−0.074**	−0.124	−0.354**	−0.247
INF	−0.001	0.013	0.014	−0.008	−0.033	−0.182***	−0.102	0.029	−0.017	−0.075	0.022	0.014	−0.028	−0.080	−0.300
TRD	0.020***	0.031***	0.044***	0.032	0.003	0.045***	0.033	0.201***	0.206***	0.124	−0.052*	−0.080***	−0.237	−0.816***	−1.041***
UMP	0.000	−0.001	−0.002	−0.004**	−0.007***	−0.006***	−0.009**	−0.011**	−0.010**	−0.018***	−0.003**	−0.002	−0.008**	−0.026***	−0.029**
MAN	0.023	−0.047	−0.399***	−0.647**	−0.290	−0.014	−0.720*	−1.478***	−2.524***	−2.460***	−0.913***	−1.138***	−1.609***	−2.139***	−2.732
Pseudo R^2	0.105	0.084	0.106	0.233	0.265	0.262	0.218	0.264	0.380	0.379	0.136	0.153	0.133	0.286	0.316

Notes: This table reports the estimation results of 61 low country risk rating countries for period t according to Eq. (1). We split our data into two (high and low) sub-groups according to total ecological footprints. The same as the notes in Tables 1 and 3

Table 8
Estimates of the QR-based economic-induced EKC hypothesis on ecological footprint models on non-financial crisis period.

Variable	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90
Built						Carbon					Crop				
C	0.110***	0.117***	0.086*	0.116	0.630***	5.210***	7.830***	10.196***	12.804***	2.456	0.252	0.759	0.595	−0.171	−0.820
REV	0.000	−0.002	−0.001	−0.008***	−0.010***	0.054	0.018	−0.007	−0.033	−0.081	0.014**	0.013*	0.010	0.004	−0.028*
ECO	0.000	0.000	0.000	−0.002***	−0.003***	−0.006	−0.013*	−0.009	0.007	0.027	0.002	0.004	0.001	−0.003	−0.001
FIN	0.000	0.000	−0.001***	0.000	0.001	−0.006	−0.001	0.004	−0.010	−0.007	−0.004**	−0.008***	−0.009***	−0.004	−0.005
POL	0.000**	0.000	0.000	0.001***	0.001	0.003	0.004	0.002	0.001	−0.004	−0.002	−0.001	−0.002	−0.002	0.004**
GDP	−0.026***	−0.022*	−0.019*	−0.023	−0.124**	−1.799***	−2.588***	−3.432***	−4.376***	−2.338***	−0.074	−0.230**	−0.163	0.144	0.424
GDP^2	0.002***	0.001**	0.001**	0.002	0.009***	0.137***	0.189***	0.246***	0.315***	0.207***	0.008**	0.018***	0.017***	0.000	−0.014
CPI	0.000***	0.000***	0.000*	0.000***	0.000*	0.002**	0.002***	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
EXG	0.000	0.001	0.000	0.003***	0.002**	0.000	−0.010	−0.017	0.034*	0.052**	−0.017***	−0.022***	−0.022***	−0.015***	−0.003
IND	0.006	0.009***	0.018***	0.038***	0.023	−0.399**	−0.052	0.491**	0.939***	1.902***	0.016	0.068*	0.082**	−0.052	−0.132*
INF	0.003	−0.006	−0.002	−0.003	−0.004	−0.216	0.069	−0.127	−0.126	2.243*	0.035	0.016	−0.012	0.139	0.179
TRD	−0.013***	−0.009***	−0.006**	−0.016***	−0.013	0.462***	0.374***	0.414***	0.223***	0.196**	−0.053***	−0.079***	−0.090***	−0.031	−0.078
UMP	−0.001***	0.000	0.001**	0.000	−0.001	0.021***	0.021***	0.021***	0.011	−0.015	0.000	0.005*	0.014***	0.009***	0.001
MAN	0.072***	0.101***	0.128***	0.179***	0.198***	3.806***	3.822***	1.360**	0.816	−4.832***	0.637***	0.615**	0.588***	0.240	0.307
Pseudo R^2	0.116	0.122	0.110	0.153	0.274	0.449	0.519	0.575	0.582	0.578	0.243	0.274	0.299	0.311	0.268
Fish						Forest					Graze				
C	0.161*	0.254***	−0.193	0.729	3.368**	0.443**	0.753**	1.087*	−1.669*	−0.828	−0.367**	−0.684***	−1.198***	−0.721	−1.685
REV	0.004***	0.009***	0.003	−0.021**	−0.055***	−0.004	−0.015	−0.036***	−0.057***	−0.150***	−0.008**	−0.004	−0.010*	−0.009	−0.066***
ECO	0.000	0.001**	0.002	0.003	0.010***	0.001	0.005*	0.004	0.019***	0.019*	0.002	0.002	0.003**	0.004	0.003
FIN	0.000	0.000	0.002	0.002	0.000	−0.001	−0.008***	−0.020***	−0.025***	−0.026**	0.003**	0.000	−0.004*	−0.010***	−0.007
POL	0.000	0.000*	0.002***	0.003**	0.003	−0.002	0.000	0.008***	0.012***	0.009***	0.000	0.001**	0.003***	0.006***	−0.005
GDP	−0.048*	−0.107***	−0.009	−0.352*	−0.950**	−0.065	−0.131	−0.094	0.766***	1.056**	0.126***	0.207***	0.406***	0.333**	0.917*
GDP^2	0.004**	0.007***	0.001	0.024*	0.062**	0.007	0.012**	0.011	−0.035**	−0.046	−0.005*	−0.009***	−0.020***	−0.016*	−0.041
CPI	0.000***	0.000***	0.000	0.000	−0.001	0.000	0.000	0.001***	0.001	0.002*	0.000**	−0.001***	0.000	−0.001	−0.004***
EXG	0.001	0.002***	0.008**	0.009**	0.004	−0.010***	−0.007**	−0.001	0.002	−0.022	−0.007**	0.000	0.001	0.000	0.011
IND	−0.022***	−0.019**	−0.027	0.238***	0.456***	−0.036	−0.008	−0.004	−0.250**	−0.309	−0.041**	−0.046**	−0.090***	−0.078	0.104
INF	0.011	0.027	0.047	−0.022	−0.036	−0.070	0.028	0.080	0.033	−0.078	0.025	0.006	−0.017	−0.066	−0.285
TRD	0.004	0.031***	0.022**	0.056*	0.023	−0.023	−0.004	0.023	0.060	−0.052	0.019***	0.019***	0.007	−0.022	−0.036
UMP	0.000	−0.001**	−0.004***	−0.008***	−0.010***	0.002	0.003	−0.005	−0.013***	−0.021**	−0.002**	−0.004***	−0.008***	−0.007**	−0.012
MAN	−0.061**	−0.041	0.122	−0.184	−1.424***	0.626***	0.636***	0.134	−0.975**	−0.345	−0.583***	−0.871***	−1.072***	−1.273***	−3.617***
Pseudo R^2	0.099	0.111	0.113	0.182	0.302	0.137	0.137	0.177	0.264	0.329	0.237	0.235	0.214	0.184	0.223

Notes: This table reports the estimation results of non-financial crisis period according to Eq. (1).. The same as the notes in Tables 1 and 3

Table 9
Estimates of the QR-based economic-induced EKC hypothesis on ecological footprint models for developing countries.

Variable	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90
Built						Carbon					Crop				
C	−0.121**	−0.065	0.107*	−0.051	−0.149*	17.874***	20.475***	23.626***	22.815***	11.713*	2.091***	2.510***	2.564***	0.837	1.977
REV	0.000	−0.001	−0.005***	−0.007***	−0.008***	0.038	0.017	−0.018	−0.020	−0.038	0.013***	0.013***	0.019***	0.013*	−0.020
ECO	0.000	0.000	0.000	−0.001**	−0.002***	−0.012*	−0.013**	−0.006	−0.009	−0.007	−0.002	−0.004*	−0.003	−0.002	0.000
FIN	0.000	0.000	0.000	0.000	0.000	0.023***	0.021***	0.018***	0.023**	0.012	−0.005**	−0.005***	−0.004*	−0.004*	−0.002
POL	0.000	0.000	0.000	0.001***	0.001***	0.004	0.012***	0.010***	0.013***	0.000	0.000	−0.001	0.000	0.000	0.005**
GDP	0.031**	0.019	−0.024	0.019	0.051**	−5.653***	−6.371***	−6.937***	−6.722***	−3.774***	−0.577***	−0.689***	−0.700***	−0.202	−0.388
GDP^2	−0.002**	−0.001	0.002**	0.000	−0.002	0.377***	0.425***	0.465***	0.463***	0.308***	0.040***	0.047***	0.048***	0.021**	0.035
CPI	0.000***	0.000**	0.000	0.000	0.000***	0.000	0.001	0.002***	0.001	−0.002	0.000	0.000	0.001***	0.001*	0.001
EXG	0.000	0.001***	0.003***	0.004***	0.003***	−0.022**	−0.029***	−0.025***	0.013	0.032	−0.017***	−0.022***	−0.029***	−0.013***	−0.015**
IND	0.009**	0.010**	0.019***	0.019*	0.026***	0.312**	0.441***	0.336***	0.218	0.437	0.066**	0.110***	0.028	−0.057	−0.127*
INF	−0.003	−0.002	0.000	−0.002	0.000	−0.012	0.077	0.048	0.414	0.265	0.042	0.023	0.203*	0.281**	0.377
TRD	0.000	0.005**	0.003	−0.009**	−0.013**	0.326***	0.227***	0.180***	0.160	0.113	−0.037*	−0.023	0.038*	0.040*	−0.028
UMP	−0.001***	−0.001***	0.000	−0.001	−0.001*	0.029***	0.023***	0.016***	0.005	−0.016	0.000	0.002	0.007***	0.006**	0.003
MAN	0.081***	0.115***	0.121***	0.133***	0.164***	3.222***	2.639***	2.482***	0.461	−4.426***	0.865***	0.776***	0.349**	−0.051	0.381
Pseudo R^2	0.150	0.153	0.147	0.201	0.292	0.483	0.546	0.597	0.620	0.622	0.312	0.333	0.353	0.338	0.288
Fish						Forest					Graze				
C	0.032	0.143	−0.097	−0.957**	−2.052**	0.858**	1.216**	2.275***	2.360**	1.478	−0.451	−1.250***	−1.516***	−1.329	−2.367**
REV	0.008***	0.012***	0.014***	0.003	−0.014	−0.003	−0.022***	−0.049***	−0.069***	−0.107***	−0.005*	−0.006*	−0.002	−0.042*	−0.141***
ECO	0.000	0.001*	0.004***	0.006***	0.003	0.001	−0.001	0.003	0.006	0.006	0.000	0.001	0.001	0.005	0.011*
FIN	0.000	0.000	0.000	−0.001	−0.005**	0.001	−0.002	−0.004	−0.003	−0.004	0.001	0.001	0.000	−0.002	0.008
POL	0.000	0.000	−0.001	0.000	0.004**	0.001	0.000	0.003*	0.006***	0.004*	0.001	0.002***	0.004***	−0.002	−0.008**
GDP	−0.046***	−0.085**	−0.053	0.213	0.554**	−0.140	−0.163	−0.186	−0.113	0.351	0.126	0.324***	0.409***	0.621***	1.310***
GDP^2	0.003***	0.005***	0.004	−0.010	−0.029**	0.012*	0.016*	0.022	0.023*	−0.002	−0.005	−0.017***	−0.022***	−0.032**	−0.068***
CPI	0.000**	0.000***	0.000**	−0.001*	−0.001***	0.000	0.000	0.000	−0.001*	0.000	0.000	0.000**	0.000*	−0.002***	−0.002
EXG	0.001**	0.001	0.005**	0.022***	0.028***	−0.015***	−0.010***	−0.007	0.006	0.013	−0.003	0.001	0.001	0.011	−0.003
IND	−0.004	−0.012	−0.042*	−0.105	−0.037	−0.129***	−0.106***	−0.345***	−0.435***	−0.483*	−0.020	−0.013	−0.062**	0.058	0.159
INF	−0.008	−0.005	0.025	0.007	−0.053	−0.004	−0.116	−0.023	0.037	−0.023	0.027	0.009	0.000	−0.149**	−0.289
TRD	0.007	0.041***	0.145***	0.220***	0.142***	−0.044**	−0.021	0.140***	0.301***	0.353***	0.012	0.012	−0.001	−0.045	−0.301**
UMP	0.000	−0.001*	−0.004***	−0.009***	−0.012***	0.000	0.000	−0.005	−0.010***	−0.009	−0.003***	−0.003**	−0.006***	−0.005	−0.018**
MAN	0.004	−0.019	0.127	0.155	−0.334	0.409***	0.828***	0.270	−1.380***	−1.828***	−0.549***	−0.815***	−1.107***	−1.899***	−2.026***
Pseudo R^2	0.100	0.088	0.139	0.241	0.292	0.114	0.119	0.193	0.307	0.366	0.161	0.168	0.129	0.141	0.276

Notes: This table reports the estimation results of 97 developing countries according to Eq. (1). The same as the notes in Tables 1 and 3

Table 10
Estimates of the QR-based economic-induced EKC hypothesis on ecological footprint models for European countries.

Variable	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90	Q10	Q25	Q50	Q75	Q90
			Built			Carbon					Crop				
C	0.071	−0.069	0.072	0.420	0.576	−14.889***	−12.753***	−15.728***	−24.972***	−23.713***	−2.851***	−3.551***	−1.251	−2.006*	−4.724***
REV	0.004**	0.004	−0.001	0.000	−0.004	0.207***	0.154***	0.172***	0.232****	0.215***	0.002	0.000	0.000	−0.033	−0.048*
ECO	−0.001	0.000	−0.001	−0.002**	−0.002	−0.009	−0.008	−0.001	−0.001	−0.002	0.007**	0.005**	0.000	0.005	0.004
FIN	0.000	0.000	0.000	0.002	0.003	0.009	0.002	0.011	0.030**	−0.001	−0.002	−0.005**	−0.001	0.001	0.005
POL	0.001**	0.002***	0.002***	0.000	−0.001	0.033**	0.026***	0.025***	0.023*	0.025**	0.002	0.000	0.002	0.003	0.005
GDP	−0.062**	−0.042	−0.037	−0.094	−0.103	1.961	1.571**	2.083***	3.880***	3.244***	0.684***	0.856***	0.409	0.798***	1.486***
GDP^2	0.003**	0.002	0.002	0.006	0.008	−0.097	−0.062	−0.089**	−0.189***	−0.148**	−0.034***	−0.041***	−0.018	−0.039***	−0.074***
CPI	0.000*	0.000***	0.001***	0.001	0.001*	−0.001	−0.001	−0.001	−0.003	−0.003	0.000	0.000	0.000	0.000	0.001
EXG	−0.003***	−0.001	0.001	−0.002	−0.001	0.037	0.077***	0.125***	0.193***	0.231***	0.009	0.007	−0.001	0.004	0.008
IND	0.023*	0.020	−0.019	−0.021	−0.042	−0.402	−0.183	−0.116	0.114	1.265*	−0.055	−0.011	−0.087	−0.239***	−0.387***
INF	0.024	0.044*	0.029	0.000	0.045	0.151	−0.031	0.136	0.325	0.751	0.250	0.163	0.187	0.234	0.348
TRD	0.019*	0.015	0.001	−0.002	−0.014	0.878***	0.662***	0.625***	0.624***	0.451*	−0.208***	−0.227***	−0.235***	−0.222**	−0.107
UMP	0.001*	0.001**	0.001	0.000	−0.002	−0.001	−0.010	−0.020**	−0.043***	−0.052***	−0.002	0.003	0.004	−0.001	−0.006
MAN	0.047	0.148*	0.428***	0.436***	0.524***	3.443**	3.691***	2.010***	−1.824	−6.698***	0.287	0.279	0.722***	0.651*	0.549
Pseudo R^2	0.191	0.210	0.254	0.307	0.360	0.476	0.531	0.556	0.467	0.459	0.298	0.307	0.238	0.177	0.222
Fish						Forest					Graze				
C	−0.501**	0.108	2.322	7.347***	18.781***	−6.648***	−4.392***	−6.768***	−16.163***	−17.706***	0.740**	0.886**	0.060	1.267	1.259
REV	−0.003	−0.008**	−0.022**	−0.062***	−0.086***	−0.088***	−0.106***	−0.110***	−0.201***	−0.271***	−0.011*	−0.014***	−0.016***	−0.009	−0.007
ECO	0.000	0.002*	0.002	0.001	−0.002	0.004	0.009*	0.006	0.027**	0.010	0.001	0.002***	0.002	0.001	0.002
FIN	0.000	0.000	0.003	0.007*	0.006	−0.005	−0.009**	−0.007	−0.011	−0.007	0.001	0.000	0.000	0.001	0.001
POL	0.001**	0.001	−0.001	−0.006**	−0.005*	0.004	0.004	0.010***	0.006	0.009	−0.001	−0.001*	−0.001	−0.002	−0.003***
GDP	0.122**	0.008	−0.519	−1.764***	−4.612***	1.942***	1.370***	1.876***	4.710***	6.014***	−0.029	−0.023	0.159	−0.287	−0.302*
GDP^2	−0.005*	0.001	0.033	0.111***	0.276***	−0.097***	−0.062***	−0.087***	−0.233***	−0.300***	0.006	0.006	−0.004	0.023*	0.024***
CPI	0.000	0.000	0.000	−0.001	−0.001	0.002***	0.001	0.002**	0.001	0.001	−0.001**	−0.001***	−0.001***	−0.002***	−0.002***
EXG	−0.002*	−0.004***	−0.013*	−0.024	−0.016	−0.069***	−0.069***	−0.079***	−0.080***	−0.071**	0.005	0.009***	0.008*	0.018**	0.027***
IND	−0.036***	−0.041*	0.070	0.462*	0.893***	−0.360***	−0.233***	−0.397***	−0.901***	−1.583***	−0.133***	−0.151***	−0.137**	0.029	0.052
INF	−0.003	−0.002	0.027	0.009	−0.098	−0.130	−0.142	0.044	−0.011	−0.282	0.086	0.057	0.031	0.016	−0.005
TRD	−0.023**	−0.022**	−0.033	−0.034	−0.102	0.057	0.086	0.291**	0.281	0.175	−0.040	−0.067***	−0.028	0.058	0.112***
UMP	0.001	0.001	0.001	0.003	0.010*	0.008***	0.012***	0.012**	−0.016*	−0.040***	−0.002*	−0.002**	−0.003**	0.002	0.001
MAN	−0.056*	−0.105*	−0.650	−1.782**	−1.512	0.557*	0.411	0.129	−1.134	−1.971	−0.674***	−0.535***	−0.712**	−0.965***	−0.905***
Pseudo R^2	0.114	0.103	0.149	0351	0.586	0.369	0.356	0.361	0.396	0.516	0.406	0.419	0.405	0.442	0.518

Notes: This table reports the estimation of 38 European countries according to Eq. (1). The same as the notes in Tables 1 and 3 of the EKC hypothesis, which depicts the overall determinants of environmental degradation.

Availability of data

Data are available from the authors upon request.

CRediT authorship contribution statement

Chien-Chiang Lee: Conceptualization, Visualization, Supervision, Writing - review & editing. **Mei-Ping Chen:** Investigation, Methodology, Software, Data curation, Writing - original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2020.123671.

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