Heliyon 10 (2024) e22849

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Exploration on terrorism, ecological footprint and environmental sustainability in countries with the most terrorism antecedent: Accessing evidence from panel fourier analysis

Cüneyt Kılıç [a], Semanur Soyyiğit [b], Yilmaz Bayar [c], Festus Victor Bekun [d,e,f,*]

[a] Çanakkale Onsekiz Mart University, Department of Economics, Çanakkale, Turkey
[b] Kirklareli University, Department of Public Finance, Kirklareli, Turkey
[c] Bandirma Onyedi Eylul University, Department of Public Finance, Balikesir-Turkey
[d] Faculty of Economics Administrative and Social Sciences, Istanbul Gelisim University, Istanbul, Turkey
[e] Research Center of Development Economics, Azerbaijan State University of Economics(UNEC), Istiqlaliyyat Str.6, Baku, 1001, Azerbaijan
[f] Adnan Kassar School of Business, Department of Economics, Lebanese American University, Beirut, Lebanon

A R T I C L E I N F O

Keywords:
Terrorism
Foreign direct investment inflows
Environmental degradation
Panel fourier cointegration test
Panel fourier toda-yamamoto causality test

A B S T R A C T

Amidst increased concerns for global security and ecological balance, the intricate interconnectedness between terrorism and environmental sustainability has attracted significant attention in the existing literature. To this end, the present study explores the interaction among environmental degradation, terrorism, and foreign direct investments in 17 countries with the most terrorism antecedents over the 2002–2018 period through the Panel Fourier cointegration test and the Panel Fourier Toda-Yamamoto causality test. The present study also leverages recent and robust panel analysis for evidence-based results and inferences for policy formulation. The panel Fourier cointegration test presents the cointegration relationship between the outline variables under review. Empirical findings highlight that terrorism does not have a significant influence on the ecological footprint. However, foreign direct investment has a positive influence on the ecological footprint. These findings have implications for environmental sustainability and foreign direct investment inflows in the bloc investigated. More insights are discussed in the concluding section with policy caveats.

1. Introduction

Environmental degradation has been accompanied with a considerable increase in production and consumption in the world since the industrial revolution and become a vital threat for the globalized world in terms of climate change and global warming, air and water pollution, biodiversity loss, soil erosion, and natural disasters. Therefore, many initiatives have been launched to protect the environment at national, regional, and international levels since 1970's. In one of these early initiatives at international level, United Nations [1] draws attention to the fact that the natural and man-made environments are vital for human being's well-being and also for enjoyment of basic human rights. Over decades, the topic maintains its importance increasingly. The UN Human Right Office also emphasizes the significance of a safe, healthy and sustainable environment for the full enjoyment of human rights such as life, health,

* Corresponding author. Faculty of Economics Administrative and Social sciences, Istanbul Gelisim University, Istanbul, Turkey.
E-mail addresses: ckilic@comu.edu.tr (C. Kılıç), semanur.soyyigit@klu.edu.tr (S. Soyyiğit), yilmazbayar@yahoo.com (Y. Bayar), fbekun@gelisim.edu.tr (F.V. Bekun).

https://doi.org/10.1016/j.heliyon.2023.e22849
Received 4 June 2023; Received in revised form 19 November 2023; Accepted 21 November 2023
Available online 28 November 2023

food, water and sanitation [2]. It is stated that putting these right at the center of crisis we face in today's World such as climate change, biodiversity and natural loss, and pollution, is much more vital now than ever in order to achieve Sustainable Development Goals (SDGs) [3]. Based on this increasing consciousness, the researchers have started exploring the factors underlying environmental degradation and numerous demographic, economic, institutional, social, and cultural factors have been suggested as the determinants of environmental degradation.

In this context, demographic characteristics, education, human development, institutional quality, industrialization, tourism; economic growth, technological development, energy consumption, urbanization, over-population growth, deforestation, financial sector development, foreign direct investment inflows, and trade openness have been documented as the factors underlying environmental degradation [4–20].For instance Ref. [21], explored the nexus ecology and health outcomes while accounting for the role of human capital development and energy consumption for Middle East and North Africa (MENA) bloc which is plagued with environmental issues with second generational framework setting. The study submits that trade-off between the ecological factors and health outcomes while an inverse nexus exists between health outcome and energy consumption. Apart from these widely studied determinants of environmental degradation, terrorist attacks and terrorism recently have been addressed as one of the key factors of this degradation [22,23]. Considering the related empirical literature on the determinants of environmental degradation and combining these economic and socio-political underlying factors, this study examines the interplay between terrorism, foreign direct investments and environmental degradation.

Terrorism can negatively affect the environment through damaging environment and infrastructure, releasing pollutants into the air [23] and disrupting the productivity and environmental and resource measures. In a very novel study [24], draws attention to that indirect impacts of terrorism on environment last longer than direct impacts. Accordingly, both official military forces and terrorist groups consume a huge amount of energy and this consumption causes a large amount of CO_2 emissions. However, the effect of terrorism is not limited with this type. Terrorists also uses various chemicals and heavy metals together with mass destruction weapons, and these chemicals and heavy metals such as iron, copper, uranium and steel) pollute air, soil and water. On the other hand, environmental degradation can foster the terrorism by allowing the terrorist groups to employ the limited resources to their advantage. In a very early study [25], states from the point of international relations that regional and global environmental deficiencies are establishing a ground for conflicts. He grouped the threats on security stem from environmental issues into four categories: (i) resources as strategic goals, (ii) attacks on resources, (iii) resources as military sources, and (iv) disruptions to environmental services. This effect of environmental degradation on terrorism has also been declared in a very recent event at the UN headquarters in New York in 2021. Accordingly, UN Secretary stated that "*Climate change is not the source of all ills. But it has a multiplier effect and is an aggravating factor for instability, conflict and terrorism.*" [26]. Therefore, a mutual interplay between terrorism and environmental degradation is possible at theoretical terms.

On the other hand, two opposite views on the impact of foreign direct investment (FDI) inflows on environment have been suggested. In this context, pollution haven hypothesis suggests that FDI inflows can lead environmental degradation in the host countries through weak environmental regulations, but pollution halo hypothesis suggest that FDI inflows can make a contribution to the improvements in environment through transfer of technology and high production standards [27]. One of these views is based on environmentalist approach while the other is based on free market efficiency [28]. According to environmentalist pollution haven hypothesis states that firms will look for ways to avoid the cost of environmental regulations by locating their productions in the environmentally lax countries. As a result, competitiveness change goes in favour of firms that make pollution-intensive manufacturing activities [29]. However, free market supporters claim that global market forces provide the best diffusion of investments by foreign companies and transfer of technology practices spreads to host developing countries. Based on the theoretical considerations, the main objective of the research is to analyze the causality among environmental degradation, terrorism, and foreign direct investments. The following research questions are discussed in the research in compatible with these objective:

What is the impact of terrorism on environmental sustainability in short and long term?

What is the impact of FDI inflows on environmental sustainability in short and long term?

The study sample covers 17 countries with the most terrorism over the 2002–2018 period namely Afghanistan, Congo, Colombia, Egypt, India, Iraq, Kenya, Mozambique, Myanmar, Nigeria, Niger, Pakistan, Philippines, Sri Lanka, Thailand, Türkiye and Yemen. The paper targets to make a contribution to the related empirical literature about determinants of environmental degradation in two ways. First, there have been a limited number of studies analyzing the mutual interaction between terrorism and environmental degradation [29]. states terrorism as 'a new and unexplored factor of environmental sustainability'. Hence, this is the main gap that the paper aims to make a contribution. Secondly and complementary, the sample of the study is another novelty of the study, because it includes 17 countries with the most terrorism in the world. In other words, the present study aims to fill the gap in the literature by examining a novel relationship for a comprehensive sample. The motivation behind this study is to examine the relationship between environmental quality as a primary human right and political/economic activities in these developing nations. Based on the findings, this study may enable us to propose some policy implementation to have a more sustainable environment which is the most prominent human right for the countries that suffer from the terrorism most.

The rest of the paper is constructed as follows: A detailed literature review about terrorism and environmental degradation is presented in Section 2 and Section 3 explains the data and research methodology, Section 4 conducts the causality analysis and evaluates the findings of the causality analysis and the article is concluded in Section 5.

2. 2. literature review

The main focus of the study is to analyze the mutual interplay among terrorism, FDI inflows, real GDP per capita, energy consumption, and environmental degradation in the selected 17 countries where terrorist incidents are experienced most intensely. Increasing terrorist incidents in the world have made terrorism the focus of national economies. Based on this point, many studies have been conducted to analyze the effects of terrorism on economic variables such as economic growth, financial markets, tourism revenues, and foreign direct investments. However, quite a few studies have already analyzed the effects of military spending and terrorism on environmental pollution/environmental degradation [30–45]. Some of these few studies focus on the relationship between defense expenditures and environmental pollution [31–39], while others focus on the relationship between terrorism and environmental pollution [30,37–41].

When the literature dealing with the relationship between military expenditures, terrorism, and environmental pollution/environmental degradation is examined, it is observed that various results have been reached. While some studies have found a positive relationship between military expenditures, terrorism and environmental degradation [31,33–35,37,38,41]. Some studies have concluded that military expenditures and terrorism reduce environmental degradation [32]. In some studies, different results were obtained on a country basis [32]. [39].

Among the studies that have a positive relationship between terrorism, military expenditures and environmental degration [31], addressed the human dimension of global environmental change in the context of its ecological footprint and the impact of military institutions on CO_2 emissions. In the study, the Treadmill of Destruction theory was used to show that the number of soldiers and the technological sophistication of the army have a significant impact on the environment. According to the findings of the study, increases in the military and technological scale and density of the army also increase the environmental impacts. Environmental degradation is positively associated with militarism, given the constant demand for resources to support military units and operations [33]. analyzed the long-term and causal relationship between economic growth, militarization, CO_2 emissions, and energy consumption for the USA using data for the period 1960–2013. According to the findings of the cointegration boundary test of the study, a positive and significant relationship was found between militarization and CO_2 emissions. According to the results of Rao's F-test, one of the other tests used in the study, a unidirectional causality relationship was observed from militarization to energy consumption, from energy consumption to CO_2 emissions, and from militarization to CO_2 emissions [34]. analyzed the relationship between cointegration and causality between militarization, economic growth, CO_2 emissions, and biofuel consumption for the USA using data from 1984 to 2015. Three extra long-term estimators such as ARDL and FMOLS, DOLS and CCR, and fully modified OLS were used in the study. In the analysis, it was found that there is a long-term cointegration relationship between the variables. In the findings of the study, a bidirectional causality relationship was found between economic growth, militarization, and biofuel consumption, between CO_2 emissions and biofuel consumption, and between CO_2 emissions and biofuel consumption and economic growth [35]. analyzed the relationship between economic growth, CO_2 emissions, militarization, and energy consumption in G7 countries using the panel data method using data from 1985 to 2015. In the study, panel trivariate causality methods and panel cointegration methods (Pedroni, PARDL, Johansen) were used. According to the results of the study, a positive and significant relationship was found between the variables in both the long and short term. While a one-way relationship was determined from energy consumption to CO_2 emissions and from militarization to CO_2 emissions, a bidirectional causality relationship was found between per capita GDP and energy consumption, between per capita GDP and militarization, and between energy consumption and militarization.

In the study by Ref. [37], the relationship between economic growth, FDI inflows, energy consumption, terrorism, and environmental pollution in Afghanistan, Iraq, Nigeria, Pakistan, Philippines, Syria, Somalia, Thailand, and Yemen were investigated with the help of data from 1975 to 2017. In the study, trivariate causality tests and different cointegration methods such as Johansen, PARDL, and Kao were used. The results of the study reveal that terrorism, FDI, and real GDP increase CO_2 emissions. According to the analyses, while there is a one-way causality relationship from FDI inflows to CO_2 emissions and from terrorism to carbon dioxide (CO_2) emissions in the short run, a bidirectional relationship has been found between CO_2 emissions and other variables such as FDI, economic growth and terrorism in the long run. In the study of (38), the effects of public expenditures and terrorism on environmental degradation in 7 countries where terrorism is intense (India, Congo, Iraq, Philippines, Yemen, Nigeria, and Pakistan) were investigated by panel data analysis method using data from the 2002–2017 period. The findings of the study revealed that public expenditures and terrorism are the causes of environmental degradation. In the study by Ref. [41], the relationship between economic growth, terrorism, foreign direct investments, environmental pollution, and energy consumption in China, India, Israel, and Türkiye for the period 1975–2017 was investigated with cointegration (Westerlund, Kao, and Pedroni) and causality (Dumitrescu and Hurlin) approaches. The results of the study revealed that foreign direct investment inflows and terrorism increase environmental pollution. In addition, a bidirectional causal relationship was found between real GDP and FDI, between energy use and damage to the environment, and between real GDP and environmental pollution.

[30], one of the studies that found that military spending and terrorism reduce environmental degration, analyzed the consumption-based environmental effects of economic development, military and ecological imbalance relations for 53 developed and underdeveloped countries, using more than one theory with the help of data from 1975 to 2000. Among the theories included in the research are the Treadmill of Destruction, The Treadmill of Production, Ecological Imbalance and Ecological Modernization. When the results of the analysis were examined, it was revealed that in the context of economic development, production increased the footprint of the treadmill per capita, while the treadmill of degradation, in the form of military expenditure per soldier, positively affected the footprints per capita. In the study by Ref. [32], the relationship between national-level militarism and consumption-based carbon dioxide emissions for 81 countries was tested by panel data method using data from 1990 to 2010. The magnitude of the effects of military personnel on carbon emissions as a percentage of the total workforce and whether military expenditures as a percentage of total gross domestic product change over time are investigated. In the study findings, it is emphasized that the environmental effects of military characteristics at both national levels are temporally stable. The study also revealed that the effects of military expenditures on emissions are greater in developed OECD countries than in developing OECD countries. The findings generally support the treadmill

perspective.

[39], one of the studies that found different results based on the country on the relationship between militarism and environmental degradation, analyzed the effects of militarism on environmental problems in 126 countries with the panel data method using the data from the period of 2000–2010. When the findings of the study were examined, it was observed that there was a negative and significant relationship between carbon emissions and military expenditures per soldier (MEPS) in the least developed countries (LDCs), while a positive and statistically significant relationship was observed in developed countries.

The empirical literature on the relationship between FDI inflows and environmental degradation have reached mixed consequences. [46–53], have uncovered that FDI inflows increased the environmental degradation, but [54–56] discovered that FDI inflows fostered the environmental improvement. However [8,57], have been concluded that the effects of FDIs on environmental degradation are different in the short and long term [58]. found an inverted U-shaped relationship between FDIs and environmental degradation. A detailed list of extant literature is presented in Table 1.

Based on literature review, the hypotheses of the article are.

Hypothesis 1. There is a relationship between terrorism and environmental sustainability in short and long run.

Hypothesis 2. There is a relationship between foreign direct investment and environmental sustainability in short and long run.

3. Research Design and methodology

The main research question of the present study is to examine the interplay among terrorism, FDI inflows, and ecological footprint. As explained in the literature section, there are many studies examining the effect of economic variables on the ecological footprint. However, the number of the studies examining the effect of terrorism on ecological footprint is quite limited. In the econometric analyses, environmental degradation is proxied by ecological footprint by Global Footprint Network. On the other hand, terrorism is represented by global terrorism index (GTI) by the Institute for Economics and Peace and the GTI assigns each country a score from 0 to 10. Within this scale, 0 corresponds to no impact from terrorism while 10 corresponds to the highest impact [59]. Lastly, FDI inflows are represented by foreign direct investment inflows from World Bank database. All series are annual and cover the 2002–2019 period. The study period is determined because GTI is available for this period. Table 2 presents the data and sources for study variables under review.

The sample of study includes Afghanistan, Colombia, Congo D. R., Egypt, India, Iraq, Kenya, Mozambique, Myanmar, Niger, Nigeria, Philippines, Pakistan, Sri Lanka, Thailand, Türkiye, and Yemen. The motivation to select this sample is the fact that these countries are the ones with the most terrorist activities in their recent history. Beyond any doubt, there are many countries suffer from these kind of terrorist activities, however we could not reach data for these countries. This lack of the data availability poses a limitation of the study. The econometric analyses are implemented through EViews 12.0, and Stata 16.0.

It is essential to test stationarity of series in econometric analysis in order to prevent spurious regression. In panel data analysis,

Table 1
Review of some previous findings on the relationship between foreign direct investments and environmental degradation.

Author(s), year	Research Method(s)	Research Results
[46]	ARDL Model	Environmental pollution is associated with FDI in Malaysia, the Philippines, and Thailand.
[54]	Dynamic simultaneous equations with panel data analysis	There is a negative relationship between FDI and CO_2 emissions.
[55]	Panel data analysis	The increase in FDI does not negatively affect air quality. Also, the study does not support the pollution haven hypothesis.
[47]	Panel cointegration test.	The increase in FDI increases environmental degradation and the environmental Kuznets curve is valid.
[48]	FMOLS panel cointegration method	The pollution haven hypothesis and the EKC curve are generally valid in the region.
[49]	Panel Granger causality tests	FDI to high-polluting industries increases CO_2 emissions per capita. There is no evidence that FDIs for other sectors cause CO_2 emissions.
[8]	ARDL model	Trade does not affect CO_2 emissions in the short and long term; while FDIs have a positive effect on CO_2 emissions in the short term, it has no effect in the long term.
[57]	System generalized moment method (system-GMM)	While FDIs improve environmental quality in the long run, they cause deterioration in environmental quality when interacting with policies and institutions in the short run.
[58]	Panel data analysis	Empirical findings reveal a one-way causality relationship from FDI to CO_2 emissions. In addition, an inverted U-shaped relationship was found between FDI and CO_2 emissions for the Asian sub-panel.
[50]	System generalized moment method (system-GMM)	FDIs have a positive effect on environmental pollution.
[51]	Multivariate regression model	There was evidence of the existence of the pollution haven hypothesis in the Balkans, while the EKC hypothesis was rejected.
[52]	Panel data analysis	Empirical findings prove the existence of the pollution haven hypothesis. In addition, in low-income countries, the increase in FDI increases environmental degradation at a higher rate.
[53]	Generalized least squares (FGLS) approach	Increases in FDI inflows will intensify carbon emissions. At the same time, it was concluded that economic development and regulatory quality reduce the impact of FDI inflows on carbon emissions.
[56]	Panel data analysis	Increases in FDI greatly reduce air quality. It has been observed that the said effect is higher in big cities than in small cities.

Source: Authors' compilation

Table 2
Definition and source of the data.

Variable	Definition	Data source
EFP	Ecological footprint (gha per person)	Global Footprint Network
GTI	Global terrorism index	The Institute for Economics and Peace
FDI	Foreign Direct Investment, net inflows (% of GDP)	World Bank

there are two groups of unit root tests: first generation unit root tests used in case of non-existence of cross section dependence and second generation unit root tests used in case of existence of cross section dependence [60]. Therefore, we first examined cross-section dependence in order to choose a proper unit root test. After testing stationary with Fourier panel LM unit root test, we applied Fourier panel cointegration test which is revealed by Ref. [61]. Cointegration coefficients were estimated with AMG estimator, and then we applied panel Fourier Toda Yamamoto causality test in order to examine causal relationship between the variables. Within this section, we will give a brief theoretical explanation of these methodologies.

Lagrange Multiplier (LM) test, developed by Breusch and Pagan, is the first one to test cross-section dependence. This test can be used when time dimension of panel data is larger than cross-section dimension. Test statistics (CDLM1) is shown as in Eq. (1) [62].

$$CDLM_1 = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\rho}_{ij}^2 \tag{1}$$

$\widehat{\rho}_{ij}^2$ in Eq. (1) refers to estimations of pairwise correlations. Under the null hypothesis of no cross-section dependence, Breusch and Pagan indicated that CDLM1 test statistics follows χ^2 distribution asymptotically. However, Pesaran developed another test that can be used for large N and T values since convenience of LM test decreases when $N\rightarrow\infty$. The test statistics of this new test (CDLM2) was a scaled version of CDLM1 test statistics [62]: as seen in Eq. 2

$$CDLM_2 = \sqrt{\frac{1}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\left(T\widehat{\rho}_{ij}^2-1\right) \tag{2}$$

Afterwards, another version of LM test was developed by Pesaran et al. Under the null hypothesis of no cross-section dependence, this test is valid for N and T tending to infinity. Besides, this test is probably to have good sample properties for both N and T. The test statistics is as follows (62): as presented in Eq. 3

$$LM_{adj} = \sqrt{\left(\frac{2T}{N(N-1)}\right)}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\rho}_{ij}\frac{(T-k)\widehat{\rho}_{ij}^2-\mu_{Tij}}{\sqrt{v_{Tij}^2}} \tag{3}$$

Another important property to examine in panel data analysis is the heterogeneity of slope coefficients. (63) developed a homogeneity test on the purpose of this examination. Hypothesis of this test is indicated as follows [63]:

$$H_0 : \beta_i = \beta, \forall i$$

$$H_1 : \beta_i \neq \beta_j$$

Based on the cross-section dependence and heterogeneity results obtained from the tests explained above, we applied Fourier panel LM unit root test extended by Ref. [64]. The authors estimated the following regression model (64): as presented in Eq. 4

$$\Delta y_{it} = \delta_{0i} + \delta_{1i}\Delta\sin\left(\frac{2\pi kt}{T}\right) + \delta_{2i}\Delta\cos\left(\frac{2\pi kt}{T}\right) + \varepsilon_{it} \tag{4}$$

Then, by applying LM principle of Schmidt and Phillips (1992) [65], they obtained the unit root test statistics from the regression model below:

$$\Delta y_{it} = \varphi_i\widetilde{S}_{it-1} + d_{ui} + d_{1i}\Delta\sin\left(\frac{2\pi kt}{T}\right) + d_{2i}\Delta\cos\left(\frac{2\mu kt}{T}\right) + v_{it} \tag{5}$$

where $\widetilde{S}_{it} = y_{it} - \widetilde{\psi}_i - \widetilde{\delta}_{0i}t - \widetilde{\delta}_{1i}\sin\left(\frac{2\pi kt}{T}\right) - \widetilde{\delta}_{2i}\cos\left(\frac{2\pi kt}{T}\right),\ t = 2, \ldots T$; $\widetilde{\delta}_{0i}, \widetilde{\delta}_{1i}\ \widetilde{\delta}_{2i}$ are estimated coefficients obtained from Equation (4); $\widetilde{\psi}_i = y_{1i} - \widetilde{\delta}_{0i} - \widetilde{\delta}_{1i}\sin\left(\frac{2\pi k}{T}\right) - \widetilde{\delta}_{2i}\cos\left(\frac{2\pi k}{T}\right)$ that y_{1i} is the first observation of y_{it} for all i. Based on Equation (5), the null hypothesis of unit root is defined by $\varphi_i = 0$ for all; and the alternative hypothesis of stationarity is defined as $\varphi_i < 0$ for some i. The LM statistic for each cross-section is defined as $\widetilde{\tau}_i(k) = \widehat{\varphi}_i / se(\widehat{\varphi}_i)$, and the panel statistic is obtained by averaging these individual statistics (66) as seen in Eq. 6

$$P_{LM}(k) = N^{-1}\sum_{i=1}^{N}\widetilde{\tau}_i(k) \tag{6}$$

Asymptotic distribution of $\widetilde{\tau}_i(k)$ depends on k, and $P_{LM}(k)$ converges to standard normal distribution that have $\xi(k)$ mean and $\zeta^2(k)$

variance [66]: as seen in Eq. 7

$$Z_{LM}(k) = \frac{\sqrt{N}(P_\tau(k) - \xi(k))}{\zeta(k)} \sim N(0,1) \tag{7}$$

The authors also indicate that the test gives good results for small sample and regardless of T > N or N > T.

Based on the results from unit root test, we applied Fourier panel cointegration test which is revealed by Ref. [61]. This cointegration test has superiority since it is robust to nonlinearity, cross section dependency and unknown number and forms of structural breaks [61]. follow the relationship between $X_{i,t}$ and $Z_{i,t}$:

$$X_{i,t} = \beta_{0,i} + \beta_{1,i} Z_{i,t} + v_{i,t} \tag{8}$$

and

$$v_{i,t} = \rho_i v_{i,t-1} + \varepsilon_{i,t} \tag{9}$$

The algorithm follows these steps: After estimating Equation (8) by OLS and obtaining the residuals $\widehat{v}_{i,t}$, in the second step Equation (9) is estimated with the OLS method, $\widehat{\rho}_i$ is obtained and residuals which is $\widehat{\varphi}_{i,t} = \widehat{v}_{i,t} - \widehat{\rho}_i \widehat{v}_{i,t-1}$ are estimated. Using the residual-based stationarity bootstrap, pseudo residuals $\{\ddot{\varphi}_{i,t}\}$ are computed by drawing with replacement from $\{\widehat{\varphi}_{i,t}\}$. Pseudo residual $\{\ddot{v}_{i,t}\}$ are computed by cumulating $\{\ddot{\varphi}_{i,t}\}$. To obtain pseudo series on $\ddot{X}_{i,t}$, $\ddot{X}_{i,t} = \widehat{\beta}_{0,i} + \widehat{\beta}_{1,i} \ddot{Z}_{i,t} + \ddot{v}_{i,t}$, where $\widehat{\beta}_{0,i}$ and $\widehat{\beta}_{1,i}$ are estimates from Equation (8). Using the dataset $\{\ddot{X}_{i,t}, Z_{i,t}\}$, Equation (8) is estimated: $\ddot{X}_{i,t} = \beta_{\dddot{0,i}} + \beta_{\dddot{1,i}} Z_{i,t} + v_{\dddot{i,t}}$. Using Equation (9) and $\{v_{\dddot{i,t}}\}$, $\ddot{\rho}_i$ is estimated. This procedure is repeated 3–7 B times, and B is advised to be set to 399 or 999. In case of nonlinearity and structural breaks, the second step explained above is modified as follows (61) as also presented in Eq. 10

$$\widetilde{v}_{i,t} = \widehat{v}_{i,t} - \widehat{\alpha}_i - \widehat{\chi}_i \sin\left(\frac{2\pi k t}{T}\right) - \widehat{\varphi}_i \cos\left(\frac{2\pi k t}{T}\right) \tag{10}$$

The null hypothesis refers to non-existence of cointegration [61]. Having detected cointegration in the panel data, the next step is to estimate the long-term coefficients. At this stage, we turn to the research of (67), who introduced a tool called the AMG estimator. This estimation method accounts for cross-section dependence by including a 'common dynamic effect' in the regression for each country. Hence, the AMG estimator has several advantages. Most importantly, the variables with different stationary levels can be used, and the cross-section dependency and heterogeneity of the parameters can be taken into consideration [67].

As a final step, we applied Fourier Toda Yamamoto causality analysis to examine the causal relationship between the variables. Since ignoring structural breaks might cause a misleading in detection of causal relationships, a novel test including Fourier function was developed by Ref. [68]. Instead of a linear VAR, the authors added intercepts depending on Fourier frequencies into the regression. Afterwards [64], developed another causality test that extending Toda-Yamamoto causality test with Fourier function. In the present study, a panel version of Fourier Toda Yamamoto causality test has been utilized following [69]. Hence, the following two-variable panel VAR model has been estimated [69]:

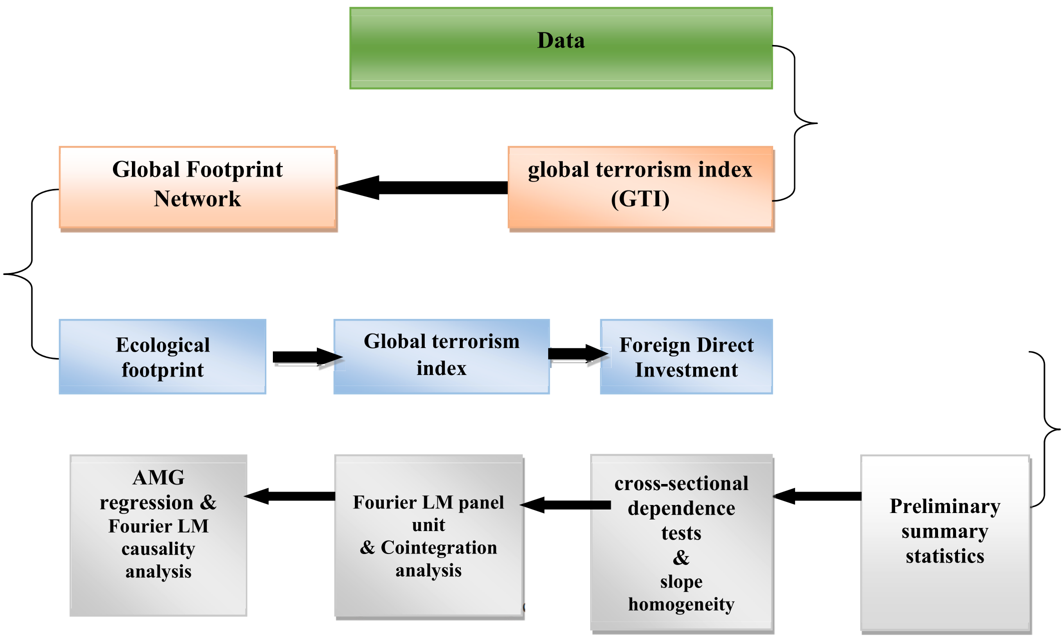

Fig. 1. Methodological schematics.

Table 3
Summary characteristics of the varibles.

EFP	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Sum	Sum Sq. Dev.	Obs.
Afghanistan	0.697344	0.69321	0.777481	0.580796	0.054325	−0.34671	2.417.962	0.580546	0.748059	1.185.485	0.04722	17
Congo D.R	0.826108	0.823755	0.885782	0.779224	0.035108	0.159495	1.652.351	1.358.521	0.506992	1.404.383	0.019721	17
Colombia	1.933.983	1.939.817	2.026.231	1.807.235	0.053758	−0.55658	3.212.196	0.90962	0.634569	3.287.771	0.046238	17
Egypt	1.823.479	1.875.294	1.963.187	1.509.241	0.151378	−104.869	2.762.338	3.155.953	0.206392	3.099.914	0.366645	17
India	0.955868	0.991967	1.209.557	0.108055	0.253525	−224.484	8.488.453	3.561.527	0	1.624.976	1.028.395	17
Iraq	1.530.363	1.509.029	1.813.391	1.276.922	0.167582	0.177272	1.775.812	1.150.573	0.562544	2.601.617	0.44934	17
Kenya	1.016.193	1.020.235	1.071.997	0.95691	0.028891	−0.246	3.011.523	0.171549	0.917801	1.727.527	0.013355	17
Mozambique	0.851152	0.842532	1.021.742	0.746021	0.064832	0.957194	3.991.824	3.292.754	0.192747	1.446.958	0.067251	17
Myanmar	1.426.351	1.417.771	1.682.857	107.019	0.174229	−0.37122	2.446.213	0.607678	0.73798	2.424.797	0.48569	17
Nigeria	1.201.423	1.182.838	13.668	1.083.888	0.086026	0.402248	2.018.245	1.141.166	0.565196	2.042.419	0.118409	17
Niger	1.577.971	157.756	1.840.374	1.319.988	0.115635	0.054824	374.589	0.402598	0.817668	268.255	0.213945	17
Pakistan	0.782548	0.771034	0.855196	0.725933	0.039373	0.378883	2.003.821	1.109.664	0.574169	1.330.331	0.024804	17
Philippines	1.211.062	1.226.057	1.467.856	1.013.756	0.106472	0.410063	3.511.172	0.661515	0.718379	2.058.805	0.181381	17
Sri Lanka	1.293.339	1.247.927	1.513.186	1.141.638	0.119713	0.608161	2.107.424	1.612.258	0.446583	2.198.676	0.229298	17
Thailand	2.252.567	2.253.417	2.575.018	1.985.151	0.147426	0.362512	2.999.536	0.372342	0.830132	3.829.364	0.347752	17
Türkiye	312.104	3.190.379	3.528.296	2.691.975	0.235689	−0.44128	2.342.861	0.857622	0.651283	5.305.769	0.88879	17
Yemen	0.8965	0.963388	1.086.171	0.508542	0.170513	−104.081	2.849.949	3.085.228	0.213821	152.405	0.465195	17

GTI	**Mean**	**Median**	**Max.**	**Min.**	**Std. Dev.**	**Skewness**	**Kurtosis**	**Jarque-Bera**	**Prob.**	**Sum**	**Sum Sq. Dev.**	**Obs.**
Afghanistan	7.983.235	8.053	9.605	5.546	1.317.812	−0.48875	2.037.643	1.332.812	0.513551	135.715	2.778.604	17
Congo D.R	5.806.471	6.095	7.081	4.057	1.064.096	−0.30492	1.609.266	1.633.447	0.441877	98.71	1.811.682	17
Colombia	6.023.647	5.949	7.04	5.516	0.397399	1.257.873	4.102.259	5.343.633	0.069127	102.402	2.526.816	17
Egypt	4.626.529	4.602	7.347	0.043	2.235.426	−0.63505	2.636.585	1.236.197	0.538968	78.651	7.995.405	17
India	7.497.294	7.512	7.797	7.157	0.181617	−0.27804	2.670.978	0.295708	0.862557	127.454	0.527756	17
Iraq	8.806.118	9.222	10	3.706	1.551.171	−236.543	8.120.261	3.442.369	0	149.704	3.849.812	17
Kenya	5.027	4.936	6.598	2.502	1.167.957	−0.48587	2.547.208	0.814091	0.665614	85.459	2.182.597	17
Mozambique	1.937.059	1.066	5.56	0	2.013.905	0.517334	1.676.623	1.998.821	0.368096	32.93	6.489.299	17
Myanmar	4.229.353	4.057	5.917	3.231	0.708034	0.958579	3.404.217	2.719.213	0.256762	71.899	8.021	17
Nigeria	6.646.118	6.227	9.278	3.509	1.957.617	−0.07884	1.643.415	1.321.174	0.516548	112.984	6.131.625	17
Niger	2.956.235	3.091	6.66	0	2.338.531	0.092972	1.777.756	1.082.657	0.581975	50.256	8.749.962	17
Pakistan	7.761.647	8.183	8.895	5.983	102.042	−0.69643	1.927.191	2.189.433	0.334634	131.948	166.601	17
Philippines	6.504	6.416	7.186	5.617	0.50839	−0.18905	1.908.755	0.944757	0.623517	110.568	4.135.366	17
Sri Lanka	5.086.824	5.132	7.081	2.893	1.384.272	0.078143	1.718.923	1.179.788	0.554386	86.476	3.065.936	17
Thailand	6.091.882	6.588	6.925	3.675	1.013.327	−14.334	364.894	6.119.778	0.046893	103.562	164.293	17
Türkiye	5.589.706	5.356	7.5	4.169	0.883866	0.713231	2.786.789	1.473.514	0.478664	95.025	124.995	17
Yemen	5.638.941	6.323	8.109	2.833	1.947.268	−0.19642	1.466.323	1.775.433	0.411595	95.862	6.066.962	17

FDI	**Mean**	**Median**	**Max.**	**Min.**	**Std. Dev.**	**Skewness**	**Kurtosis**	**Jarque-Bera**	**Prob.**	**Sum**	**Sum Sq. Dev.**	**Obs.**
Afghanistan	1.251.667	0.661572	4.364.535	0.209665	1.309.883	1.335.679	3.411.749	5.174.868	0.075213	2.127.834	2.745.269	17
Congo D.R	4.791.617	3.972.163	1.271.601	−130.414	3.734.008	0.704146	2.681.179	1.476.826	0.477872	8.145.749	2.230.851	17
Colombia	386.949	4.176.887	7.028.893	1.817.908	1.224.844	0.474157	4.017.058	1.369.709	0.504164	6.578.133	2.400.387	17
Egypt	3.168.893	2.438.563	9.348.567	−0.20454	2.807.054	1.054.657	3.113.874	3.160.708	0.205902	5.387.118	1.260.728	17
India	1.706.051	1.635.034	3.620.522	0.605889	0.736139	0.800291	3.906.584	2.396.828	0.301672	2.900.287	8.670.412	17
Iraq	−0.23298	0.819048	4.561.717	−454.159	2.491.391	−0.35704	2.470.452	0.559809	0.755856	−396.061	993.125	17
Kenya	1.072.033	0.883794	3.094.681	0.113202	0.930175	0.745389	2.352.228	1.871.435	0.392304	1.822.457	1.384.361	17
Mozambique	1.511.825	1.130.322	394.562	1.433.069	1.214.569	0.627226	2.023.646	1.789.898	0.408628	2.570.102	2.360.284	17
Myanmar	3.723.005	343.795	7.818.259	22.185	1.624.438	1.170.224	3.565.013	4.106.163	0.128339	6.329.108	4.222.078	17
Nigeria	1.606.692	1.667.213	2.900.249	0.195183	0.80009	−0.07122	1.977.242	0.755314	0.685466	2.731.377	1.024.231	17
Niger	4.621.502	3.638.493	1.216.451	0.281341	3.793.252	0.518049	1.987.073	1.487.161	0.475409	7.856.554	2.302.202	17
Pakistan	1.309.632	0.924442	3.668.323	0.382827	1.029.796	1.345.889	3.340.121	5.214.289	0.073745	2.226.375	1.696.768	17
Philippines	1.588.967	154.906	3.122.387	0.513698	0.813362	0.32612	2.061.643	0.925034	0.629697	2.701.243	1.058.492	17
Sri Lanka	1.318.205	1.211.327	1.863.973	0.841873	0.340582	0.363553	1.923.765	1.194.934	0.550204	2.240.948	1.855.939	17
Thailand	2.759.183	2.938.249	4.339.584	0.667087	1.143.441	−0.39848	2.157.887	0.9522	0.621201	4.690.612	2.091.931	17
Türkiye	1.685.969	1.560.831	3.623.502	0.450358	0.864757	0.71835	3.061.686	1.464.772	0.480761	2.866.148	1.196.488	17
Yemen	0.584197	−0.04022	5.880.659	−180.372	2.444.531	1.254.728	3.353.852	4.549.325	0.102832	9.931.357	9.561.168	17

$$y_{i,t} = \mu_i + \sum_{j=1}^{k_i+d_{max_i}} A_{11} y_{i,t-j} + \sum_{j=1}^{k_i+d_{max_i}} A_{12} x_{i,t-j} + A_{13} \sin\left(\frac{2\pi t f_i}{T}\right) + A_{14} \cos\left(\frac{2\pi t f_i}{T}\right) + u_{i,t}$$

$$x_{i,t} = \mu_i + \sum_{j=1}^{k_i+d_{max_i}} A_{21} y_{i,t-j} + \sum_{j=1}^{k_i+d_{max_i}} A_{22} x_{i,t-j} + A_{23} \sin\left(\frac{2\pi t f_i}{T}\right) + A_{24} \cos\left(\frac{2\pi t f_i}{T}\right) + u_{i,t}$$

The null hypothesis refers to no causal relationship. In this test, firstly both equations above are estimated for each cross-section units and a Wald test is applied to the restriction of the first k lags for corresponding variable, and then bootstrap p value is computed. Fisher test statistics for panel Fourier Toda Yamamoto (FTYP) is formulized as follows [69]:

$$FTYP = -2 \sum_{i=1}^{N} \ln\left(p_i^*\right) \tag{11}$$

In Equation (11), p_i^* refers to the bootstrap p values correspond to the Wald statistics for the cross-section i. Fig. 1 outlines a graphical schematic of the methodological sequences.

4. Empirical results and discussion

This section focuses on the stylised fact about the empirical result and discussion. This section set off with preliminary analysis after the study of [21] on basic summary statistics that outlines measure of central tendencies and measure of dispersion to underscore how the variables under consideration fare as presented in Table 3. Subsequently, in the econometric analysis, cross-sectional dependence and heterogeneity are firstly investigated following [21] for specification of unit root, cointegration, and causality test. The cross-sectional dependence is tested by CD_{lm1} test of [70] and CD_{lm2} and CD_{lm3} tests of [62] and LM_{adj} test of [71] and tests' results were shown in Table 4. The results of CD_{lm1}, CD_{lm2} and CD_{lm3} tests unveil the presence of cross-sectional dependence for three variables and panel model. However, the results of LM_{adj} test reveals the presence of cross-sectional dependence for EFP, GTI, and panel model, and cross-sectional independence for FDI variable. As a result, a shock in a country of panel can influence the other countries in the panel.

The homogeneity of slope coefficients is tested with delta tilde and delta tilde$_{adj}$ tests of [63] and presented in Table 5. The test results uncover that the slope coefficients are not homogeneous.

The stationarity of EFP, GTI, and FDI is analyzed with modified Fourier panel LM unit root test of (66) and the test findings are shown in Table 6. The findings indicate that the variables have unit root at their level values.

The cointegration relationship between dependent and independent variables are tested separately by through [61] panel Fourier cointegration test. First, the cointegration relationship between EFP and GTI is investigated and the findings are reported in Table 7 and unveils a significant cointegration between EFP and GTI at both country and panel levels considering GLS and PP results.

Secondly, the cointegration relationship between EFP and FDI is investigated through panel Fourier cointegration test and the findings are reported in Table 8 and uncovers a significant cointegration between EFP and FDI at both country and panel levels considering GLS and PP results.

The cointegration coefficients are estimated through AMG estimator after a significant cointegration among EFP, GTI, and FDI was revealed and the estimation results are presented in Table 9. The panel cointegration coefficients indicate that GTI does not have a significant influence on EFP, but FDI has a positive influence on EFP. However, the country level cointegration coefficients denote that GTI positively affects the EFP in Congo D. R. and Myanmar, but GTI negatively affects the EFP in Iraq, Nigeria, Mozambique, and Sri Lanka. On the other hand, FDI positively affects the EFP in Pakistan, Philippines, and Mozambique, but negatively affects the EFP in Afghanistan.

The causality connection between EFP and GTI is investigated through Fourier Toda-Yamamoto causality test and the consequences

Table 4
Findings of cross-sectional dependence tests.

Variables	*EFP*		*GTI*		*FDI*	
Tests	Test statistics	P value	Test statistics	P value	Test statistics	P value
CD_{lm1} (BP,1980)	54,935***	0,000	41,786***	0,004	47,827***	0,001
CD_{lm2} (Pesaran, 2004)	5236***	0,000	3207***	0,001	4139***	0,000
CD_{lm3} (Pesaran, 2004)	−3831***	0,000	−3863***	0,000	−3307***	0,000
LM_{adj} (PUY, 2008)	3919***	0,000	2959***	0,002	0038	0,485
Cointegration Equation						
			Test statistics		**P value**	
CDlm1 (BP,1980)			183,816***		0,004	
CDlm2 (Pesaran, 2004)			2899***		0,002	
CDlm3 (Pesaran, 2004)			1992**		0,023	
LMadj (PUY, 2008)			15,210***		0,000	

Table 5
Findings of slope homogeneity tests.

Tests	Test statistics	P value
Delta Tilde	7844***	0,000
Delta Tilde$_{adj}$	8970***	0,000

of causality analysis are displayed in Table 10. The test consequences uncover a unidirectional causality from GTI to EFP in Egypt, India, Myanmar, and Sri Lanka, but a unidirectional causality from EFP to GTI in Niger, Thailand, Türkiye, and Yemen. This outcome resonates with the study of [22] as terrorism influences environmental sustainability.

The causal interplay between EFP and FDI is investigated through Fourier Toda-Yamamoto causality test and the consequences of causality analysis are displayed in Table 11. The test consequences uncover a unidirectional causality from FDI to EFP in Congo D. R., Egypt and Sri Lanka, a unidirectional causality from EFP to FDI in Iraq, Myanmar, Pakistan, Thailand and Yemen, and a bidirectional causality between EFP and FDI in Sri Lanka. This result is in line with the study of [72] for belt and road initiative countries as well as the study of [73].

5. Conclusion and policy implication

5.1. Conclusion

The nexus between terrorism and environmental degradation is a dynamic relationship where environmental indices can both simultaneously enhanced and amplify terrorism while also suffering the adverse implications. To this end,the case for environmental sustainability has been a source of concern for both government administrator and energy practitioner. The motivation for environmental sustainability is in alignment with both national and international environment agreement such as the Paris Agreement goal and United National Sustainable Development Goals Goal-13 that highlights the need for climate mitigation. To this end, the present panel study renders a new perspective to the terrorism-environment and sustainability literature that has receive paucity of documentation in the extant literature. The present study explores the connection between terrorism and its spillover effect on environmental sustainability for most terrorism countries as outlined by global terrorism index database. On this premise, the present study primary aims to explore if terrorism influences ecological footprint or vice versa in a panel framework. The current study relies on robust and recent panel econometrics that circumvent for cross-sectional dependency issues and homogeneity issues by employing the Fourier panel LM unit root test, we applied Fourier panel cointegration and for long run equilibrium relationship, we employed the Augmented Mean Group (AMG) estimator.

The present study offers several empirical results that hold huge policy suggestions and implications for the blocs investigated. For instance, the results that terrorism does not have effect on ecological footprint as outline in the overall panel. This result suggests that ecological imbalances does not have effect on environmental sustainability for the study bloc. However, there is need for more country-specific action step on the part of these countries Congo D.R., Iraq, Mozambique, Myanmar, Nigeria, Sri Lanka, Türkiye on the need for terrorism activities as terrorism have positive effect on ecological footprint (environmental sustainability). The plausible logic is due to the economic disposition of these outlined countries as they are developing with vert low-income per capita and very weak institutions that compact terrorism activities that translate into environmental issues. From a policy standpoint, the highlighted countries are enjoined to strengthen institutions via legislation to compact terrorism activities. Additionally, there is need to increase the livelihood of her citizenry i.e., (decent work- UNSDGs-8), this action step will engage the citizen of Congo D.R., Iraq, Mozambique, Myanmar, Nigeria, Sri Lanka, Türkiye and in long run mitigate adverse effect on ecological footprint which translate into clean ecosystem of these countries.

Furthermore, the present study gives credence to the FDI- pollution argument for the over all sample area. This outcome is informative to both investigated countries government administrators and environmentalist. This result calls for policy action on mitigating actions on FDI inflow into these countries as most multinational companies dumps waste and bye product to these countries as these countries are known to have very weak environmental laws. Actions steps such as more stringent environmental laws on multinational on FDI inflow in form of green field should be watched closed. Furthermore, there is need for activation of pollution tax as observed in other developed blocs to deter defaulting multinationals. Otherwise, the gain of trade flow in form of FDI will be detrimental to these countries.

5.2. Policy implications

The emergence and convergence between environmental degradation and terrorism have necessitated the need for more robust and comprehensive policy architecture from government administrators and all related stakeholders that holistically captures security threats and prioritizes environmental resilience in top terrorism as outlined in the present study. These policies range from effective strategies that capture resources management, conflict prevention and community engagement, collaboration from government and private sector at national and global level that holistically mitigate counter terrorism without also compromise for environmental sustainability. Furthermore, from the environmental side, policies that encapsulate conflict-sensitive strategies should be pursued in resources management to help exacerbate tension and conflict in resources allocation. Pragmatic efforts that promote biodiversity without adverse effect on livelihood and socioeconomic stability. Furthermore, the investigated blocs are urged to pursue strong

Table 6
Fourier LM panel unit root test results.

	EFP			GTI			FDI		
Countries	Fouriertau LM_1 k = 1	Fouriertau LM_1 k = 2	Fouriertau LM_1 k = 3	Fouriertau LM_1 k = 1	Fouriertau LM_1 k = 2	Fouriertau LM_1 k = 3	Fouriertau LM_1 k = 1	Fouriertau LM_1 k = 2	Fouriertau LM_1 k = 3
Afghanistann	−3,6848	−1,2683	−1,0297	0,6214	−0,5899	−1,2610	0,0276	−1,9114	−1,2723
Colombia	−2.3165	−0,8405	−0,4557	−1,7503	−0,2589	−2,2530	−3,3744	−2,6199	−4,1395
Congo D. R.	−1.0724	−1,9052	−0,8578	−2,2303	−1,9421	−1,7045	−1,6540	−1,4283	−4,0334
Egypt	−1.3718	−1,2658	−1,7326	−1,9551	−2,4125	−1,9954	−1,1931	−2,1414	−0,5551
India	−1.6753	−3,3059	−1,3821	−1,6417	1,0187	−3,1640	−0,9585	−5,2539	−1,7119
Iraq	−3,3525	−2,4070	−1,8194	−0,3504	−0,9107	0,3219	−2,3837	−0,962	−1,6503
Kenya	−3.0627	−0,8943	−0,7575	−1,5277	−1,0934	−0,5173	−4,9658	−6,9389	−4,5298
Mozambiqu	−2.4067	−2,6186	−2,2374	−1,0126	0,9176	−0,0129	−3,7506	−1,6196	−1,9124
Myanmar	−1.4333	−0,3958	−1,0146	−1,9422	−1,1352	−0,3485	−2,1329	−1,3658	−1,0148
Niger	−0.6311	−0,3027	−0,3595	−0,1037	0,7774	0,6737	−1,5417	0,0169	0,3749
Nigeria	−1,6473	−0,3339	−0,2683	−2,1729	−1,9135	−3,3131	−3,1760	−0,3981	−0,1587
Pakistan	−2,3501	−0,2639	−0,6542	−0,5468	−2,0678	−2,3574	−0,9269	−2,3044	−0,9107
Philippines	−0.7568	−1,8763	−1,7733	−1,9534	−0,2779	−0,4835	−2,2763	−1,3840	−2,7321
Sri Lanka	−1.6886	0,2244	0,2437	−1,2353	0,1881	−4,0263	−1,0693	−3,3250	−1,8948
Thailand	−1.4679	−1,0997	−0,1377	−2,0261	0,7242	−2,3828	−2,3590	−1,7969	−2,3330
Türkiye	−1.6160	−1,4020	−1,4753	−2,6530	−0,9153	−2,3087	−1,7029	−1,7739	−0,7478
Yemen	−1,2609	−1,2347	1,0836	−2,0119	−1,7283	−1,1104	−1,1562	−3,7467	−2,2727
Panel results rowhead									
Z_{LM} (İst.Değeri)	7.2543	5,5117	7,6178	10,1351	8,7123	3,3216	6,1502	−0,4285	1,8526
p-value	1.0000	1,0000	1,0000	1,0000	1,0000	0,9996	1,0000	0,3342	0,9161

Table 7
Cointegration betwee EFP and GTI.

Countries	GLS					PP				
	Test statistics	1 %	5 %	10 %	k	Test statistics	1 %	5 %	10 %	k
Afghanistan	−4.233***	−3.638	−2.543	−1.254	1.400	−3.711***	−3.157	−2.168	−0.767	1.400
Colombia	−3.995***	−3.174	−1.750	−0.057	0.1	−6.391***	−2.765	−1.636	0.886	0.1
Congo D.R.	−4.299***	−3.538	−2.227	−0.743	1.400	−7.066***	−3.384	−2.080	−0.518	1.400
Egypt	−3.954***	−3.543	−2.398	−1.239	0.1	−4.213**	−4.344	−2.115	−1.005	0.1
India	−4.171***	−3.567	−2.010	0.474	1.700	−6.710***	−3.702	−1.908	1.804	1.700
Iraq	−3.983***	−3.195	−1.812	−0.401	1.900	−4.106***	−2.631	−1.625	−0.225	1.900
Kenya	−4.539***	−3.754	−2.624	−0.64	1.900	−6.108***	−3.444	−2.390	−0.697	1.900
Mozambique	−3.847***	−3.607	−2.530	−1.071	1.800	−3.766**	−3.767	−2.449	−1.270	1.800
Myanmar	−3.659***	−3.008	−2.063	−0.97	1.100	−4.214***	−2.879	−1.970	−1.227	1.100
Niger	−3.252**	−3.323	−2.058	−0.764	1.300	−3.689***	−3.000	−1.941	−0.909	1.300
Nigeria	−5.016***	−3.600	−2.517	−0.815	1.900	−4.714***	−3.656	−2.424	−0.571	1.900
Pakistan	−4.147***	−3.287	−1.962	0.092	1.500	−4.075***	−3.009	−1.907	0.677	1.500
Philippines	−4.121***	−3.493	−2.478	−0.545	0.4	−4.015**	−4.326	−2.453	−0.656	0.4
Sri Lanka	−4.194***	−4.066	−2.653	−1.097	1.800	−6.977***	−6.160	−2.898	−1.324	1.800
Thailand	−3.406**	−3.476	−1.603	0.391	1.900	−3.310***	−2.595	−1.327	2.838	1.900
Türkiye	−5.486***	−3.981	−2.572	−1.096	1.600	−7.310***	−4.490	−2.478	−0.985	1.600
Yemen	−6.096***	−4.061	−2.780	−0.471	1.900	−13.947***	−4.256	−2.686	−0.485	1.900
Panel Mean	−4.259**		**Prob**	0.027		**Panel Mean**	−5.548**		**Prob**	0.03
Panel Max	−6.096***		**Prob**	0.003		**Panel Max**	−13.947***		**Prob**	0.001
Panel Median	−4.147**		**Prob**	0.035		**Panel Median**	−4.214*		**Prob**	0.059

***, **, * respectively indicate that they are significant at 1 %, 5 %, and 10 %.

Table 8
Cointegration between EFP and FDI.

Countries	GLS					PP				
	Test statistics	1 %	5 %	10 %	k	Test statistics	1 %	5 %	10 %	k
Afghanistan	−3.910***	−3.677	−2.320	−0.314	1.900	−4.601***	−3.539	−2.059	−0.537	1.900
Colombia	−3.927***	−3.092	−1.907	0.272	0.1	−6.210***	−3.772	−1.933	1.048	0.1
Congo D. R.	−4.242***	−2.976	−1.831	0.051	1.900	−4.203***	−2.966	−1.837	1.240	1.900
Egypt	−6.073***	−4.227	−2.422	−0.323	1.500	−12.531***	−4.907	−2.424	0.309	1.500
India	−4.218***	−3.493	−1.771	1.231	1.700	−6.431***	−3.424	−1.756	1.046	1.700
Iraq	−3.920***	−3.640	−2.305	−0.812	1.900	−4.861***	−3.222	−2.037	−0.875	1.900
Kenya	−3.872***	−3.406	−2.005	0.133	1.900	−5.089***	−3.360	−1.887	0.685	1.900
Mozambique	−3.983***	−3.058	−1.861	0.274	1.900	−3.828***	−3.097	−1.782	0.823	1.900
Myanmar	−5.403***	−3.590	−2.217	−0.736	0.1	−5.567***	−3.416	−2.105	−0.419	0.1
Niger	−2.723**	−2.905	−1.559	0.156	1.900	−2.947***	−2.755	−1.407	3.286	1.900
Nigeria	−3.388**	−3.590	−2.715	−1.233	1.600	−3.390**	−4.335	−2.691	−1.070	1.600
Pakistan	−3.659***	−3.331	−2.292	−0.091	1.900	−3.880**	−4.433	−2.178	0.393	1.900
Philippines	−3.830***	−3.510	−2.345	−1.056	1.600	−5.994***	−3.535	−2.265	−1.131	1.600
Sri Lanka	−11.387***	−2.798	−1.901	0.201	0.6	−6.458***	−3.365	−1.975	1.414	0.6
Thailand	−4.211***	−2.940	−2.178	−0.189	1.900	−4.571***	−3.142	−2.088	−0.614	1.900
Türkiye	−4.538***	−3.117	−2.078	0.424	1.900	−5.751***	−4.492	−2.289	0.569	1.900
Yemen	−4.754***	−3.482	−2.117	−0.869	0.1	−4.556***	−3.667	−2.144	−0.748	0.1
Panel Mean	−4.591**		**Prob**	0.013		**Panel Mean**	−5.345**		**Prob**	0.026
Panel Max	−11.387***		**Prob**	0		**Panel Max**	−12.531***		**Prob**	0
Panel Median	−3.983**		**Prob**	0.043		**Panel Median**	−4.861**		**Prob**	0.036

***, **, * respectively indicate that they are significant at 1 %, 5 %, and 10 %.

institutional law to fortify their economy against dumping by big multinational firms. There is also need for government officials to improve economic activities to productively engage her citizens. As there is a trade-off between terrorism and economic productivity as established in the related literature.

5.3. Limitation to the study

Although the current study explores the connection and causality flow between terrorism, FDI on ecological footprint for most terrorism blocs. There is need for more exploration on the theme by exploring the pivotal role of income per capita and other demographic indices such as population, urbanization, and industrialization etc. Future studies can explore the theme while controlling for the highlighted indicators and explore other developing blocs such as SSA, MENA to ether refute or validate our study position.

Table 9
Cointegration coefficients' estimation (AMG).

	GTI			FDI		
	Coefficients	Std. Error	P value	Coefficients	Std. Error	P value
AMG	−0,017875	0,15906	0,261	0,017625**	0,0074758	0,018
Country Coefficients						
Afghanistan	−0,0208535	0,0197098	0,290	−0,0284732***	0,010012	0,004
Colombia	0,0424219	0,0611729	0,488	−0,0032219	0,0140876	0,819
Congo D.R.	0,0226852***	0,0066069	0,001	−0,0004359	0,0013329	0,744
Egypt	−0,0043049	0,0043843	0,736	0,0043843	0,0070823	0,536
India	−0,2117316	0,5497224	0,700	0,059836	0,1208433	0,620
Iraq	−0,0674532**	0,0333078	0,043	−0,0050056	0,016073	0,755
Kenya	0,0064271	0,0100164	0,521	0,0023865	0,0092068	0,795
Mozambique	−0,0317966***	0,0074424	0,000	0,0033551***	0,0010767	0,002
Myanmar	0,0738879**	0,0308869	0,017	0,0101024	0,012521	0,420
Niger	−0,0035625	0,0175869	0,839	0,0004925	0,0092627	0,958
Nigeria	−0,0496615***	0,0177277	0,005	−0,0020008	0,0274602	0,942
Pakistan	−0,0016447	0,0129748	0,899	0,0283721***	0,0074044	0,000
Philippines	0,0210238	0,056129	0,708	0,0867854***	0,0307356	0,005
Sri Lanka	−0,0593189***	0,012862	0,000	0,074915	0,486675	0,124
Thailand	0,038089	0,0526199	0,469	0,0386973	0,0278871	0,165
Türkiye	0,0553464*	0,0327743	0,091	0,0188129	0,031703	0,553
Yemen	−0,0680582	0,0430738	0,114	0,0106226	0,0186907	0,570

***, **, * respectively indicate that they are significant at 1 %, 5 %, and 10 %.

Table 10
Causality analysis between EFP and GTI.

Country	EFP ↛ GTI			GTI ↛ EFP			Results
	Test statistics	Frequency	p values	Test statistics	Frequency	p values	→ ↔ —
Afghanistan	0,148359	1	0,700	1,39718	1	0,450	EFP — GTI
Colombia	0,378514	1	0,350	0,448632	1	0,450	EFP — GTI
Congo D.R.	3,294243	2	0,200	0,31201	2	0,700	EFP — GTI
Egypt	0,012733	1	0,950	3,880826***	1	0,000	GTI → EFP
India	0,824546	1	0,450	3,271933**	1	0,050	GTI → EFP
Iraq	0,179237	2	0,700	1,64113	2	0,200	EFP — GTI
Kenya	0,854956	1	0,400	0,131629	1	0,500	EFP — GTI
Mozambique	1,169923	1	0,300	0,291666	1	0,450	EFP — GTI
Myanmar	1,058393	1	0,500	5,3242***	1	0,000	GTI → EFP
Niger	3,636547**	1	0,050	0,524518	1	0,300	EFP → GTI
Nigeria	0,088602	1	0,600	0,234534	1	0,550	EFP — GTI
Pakistan	0,498075	2	0,600	0,583232	2	0,400	EFP — GTI
Philippines	1,72647	1	0,200	0,751467	1	0,450	EFP — GTI
Sri Lanka	0,0729	1	0,750	9,970989***	1	0,000	GTI → EFP
Thailand	4,632026***	2	0,000	1,203592	2	0,150	EFP → GTI
Türkiye	7,742543***	2	0,000	1,487633	2	0,250	EFP → GTI
Yemen	6,912718***	2	0,000	0,274331	2	0,500	EFP → GTI

***, **, * respectively indicate that they are significant at 1 %, 5 %, and 10 %.

Data availability statement

Data will be made available on request.

Additional information

No additional information is available for this paper.

Funding

No funding has been received toward the research.

Ethics approval and consent to participate

Not applicable.

Table 11
Causality analysis between EFP and FDI.

Country	EFP ↛ FDI			FDI ↛ EFP			Results
	Test statistics	Frequency	p values	Test statistics	Frequency	p values	→ ↔ —
Afghanistan	1,260878	1	0,250	0,073145	1	0,850	EFP — FDI
Colombia	0,12475	1	0,600	0,006613	1	0,950	EFP — FDI
Congo D.R.	1,050176	1	0,300	6,33834***	1	0,000	FDI → EFP
Egypt	2,345867	1	0,350	7,915247***	1	0,000	FDI → EFP
India	0,003659	1	0,950	0,463944	1	0,400	EFP — FDI
Iraq	2,408188***	2	0,000	0,135987	2	0,650	EFP → FDI
Kenya	0,920106	1	0,450	0,345078	1	0,600	EFP — FDI
Mozambique	0,403927	1	0,550	1,013257	1	0,350	EFP — FDI
Myanmar	3,798822*	3	0,100	0,061971	3	0,750	EFP → FDI
Niger	1,793431	1	0,300	1,531784	1	0,450	EFP — FDI
Nigeria	0,161034	2	0,700	0,282172	2	0,600	EFP — FDI
Pakistan	2,259589*	1	0,100	0,763905	1	0,500	EFP → FDI
Philippines	0,998071	1	0,350	0,847022	1	0,400	EFP — FDI
Sri Lanka	6,014372**	1	0,050	2,809805*	1	0,100	EFP ↔ FDI
Thailand	1,669077*	1	0,100	0,398021	1	0,350	EFP → FDI
Türkiye	0,608224	2	0,600	0,014008	2	0,850	EFP — FDI
Yemen	5,326441*	3	0,100	0,708493	3	0,350	EFP → FDI

***, **, * respectively indicate that they are significant at 1 %, 5 %, and 10 %.

Consent for publication

Not applicable.

CRediT authorship contribution statement

Cüneyt Kılıç: Conceptualization. **Semanur Soyyiğit:** Formal analysis, Data curation. **Yilmaz Bayar:** Writing - original draft, Methodology, Investigation. **Festus Victor Bekun:** Writing - review & editing, Supervision, Funding acquisition.

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.

Acknowledgement

We sincerely acknowledge the Editors and the anonymous referees.

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