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# Impact of tourism industry, globalization, and technology innovation on ecological footprints in G-10 countries

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## ABSTRACT

In the past couple of years, most of the countries observed an increase in the size of their ecological footprints. Therefore, researchers and policymakers are now more focused on the potential drivers through which the ecological deficiency can be reduced. In the same context, this study evaluates international tourism, globalization, and technology innovation effects on the ecological footprints of G-10 countries over the period of 1995–2019. This study initially applied second-generation cross-sectional dependency, unit root, and cointegration tests. The long-run and short-run estimates were obtained through the Cross-Sectional ARDL method. The study's empirical findings demonstrate that tourism, globalization, and economic growth significantly contributed to ecological footprint, while technology innovation reduced the environmental burden, thus leads to a decline in ecological footprints of sample countries. These results suggest the use of alternate energy resources and advanced technology in the tourism industry.

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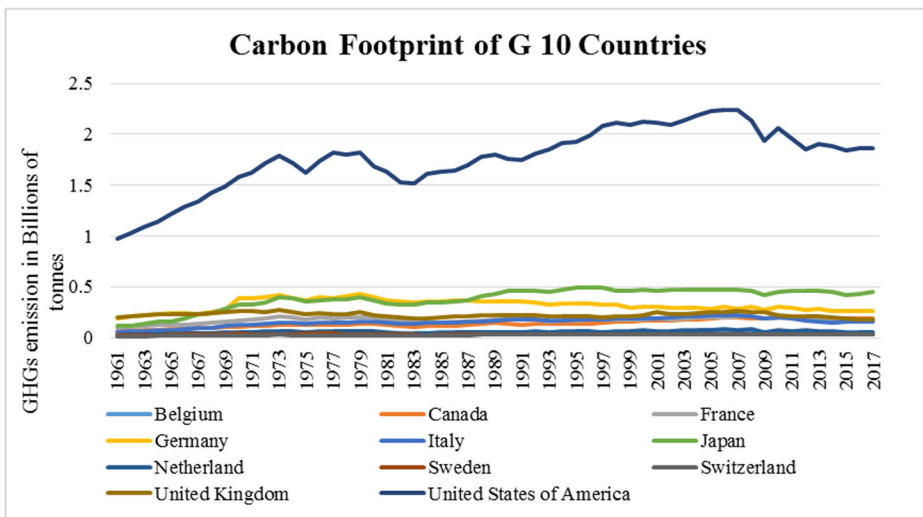
## 1. Introduction

With the carbon neutrality targets, the sustainable development of the environment has become the prime concern of all countries over the last couple of years (Caglar et al., 2021; Tao et al., 2021). The diversified social, economic, and environmental human activities have induced a tradeoff between economic performance and environmental sustainability (Liu et al., 2022; Nathaniel et al., 2021b). Various studies have used ecological footprint (EF) as a reliable measure of environmental quality (Anser et al., 2021; Godil et al., 2020; Shokoohi et al., 2022). The EF is the comprehensive matrix to compare the resources consumption and waste production by humans with

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**Figure 1.** Carbon footprint of G-10 countries. Source: Global Footprint Network 2017, <https://data.footprintnetwork.org/>.

nature's resource regeneration and waste absorption capacity (Nathaniel et al., 2021a; Ozturk et al., 2016; Usman & Makhdum, 2021). The boom in industrialization, tourism, financial and economic growth, and globalization has significantly reduced the ecological reserve and increased the ecological footprint globally (An et al., 2021; Sarkodie, 2021; Udemba & Keleş, 2021).

The major and rapidly growing component of the ecological footprint is the carbon footprint used to measure the fossil fuel-related greenhouse gas emissions or a 'carbon weight of kilograms or tonnes per person or activity tonnes per year' (Wiedmann & Minx, 2008). The increase in carbon concentration in the environment refers as the ecological debt. Currently, the carbon footprint composes more than 60% of the overall EF of the world (Global Footprint Network, 2019). Figure 1 demonstrates the carbon footprint of G-10 countries from 1961 to 2017. It has clearly been observed that the USA has the highest carbon footprint throughout all these years among all groups of ten countries. At the same time, other countries are individually responsible for emitting greenhouse less than 0.5 billion tonnes of GHGs in a year.

The group of Ten (G-10) is the group of eleven industrial countries with similar economic interests. The primary objective of the G10 group is to coordinate fiscal and monetary policies to foster economic stability worldwide. The members of the group are Belgium, Sweden, France, Germany, Japan, Italy, Canada, Netherlands, Switzerland, UK and USA (IMF, 2021).

Currently, the growing carbon footprint is the prime concern of scholars, who link different economic and environmental determinants with EF to provide better solutions. Similarly, the study's objective is to evaluate the impact of the tourism industry, globalization, and technology innovation on ecological footprints in G-10 Countries. For this purpose, the study incorporates the annual series of variables for G-10 countries from 1995 to 2017.

The tourism industry (TOR) significantly contributes to economic advancement (Adedoyin et al., 2021; Song et al., 2021). Tourism accelerates the earnings of the transportation sector (Tahir & Rafiq, 2021), improves the development of infrastructure, promotes trade activities (Tang, 2021), and abates unemployment (Ozturk & Acaravci, 2009; Sharma & Mitra, 2021). Although tourism has a great influence on economic stability, at the same time, its deteriorating impact on the environment is also very high. TOR is directly linked with the high fossil fuel energy consumption through transportation which causes more than 75% of the total carbon emission related to tourism activities (Zhang & Liu, 2019), moreover tourism requires the proper development of the infrastructure, the excessive exploration to the natural resources grow the carbon footprint and deplete the biocapacity (Nathaniel et al., 2021b; Razzaq et al., 2021a).

Globalization (GLB) is another key driver that can significantly affect the environment. It refers to an increasing link between the countries through the social, economic, and political aspects (Rehman et al., 2021), for instance, globalization increases trade activities, financial integration, sharing of information, technological transfer, economic growth, and total factor productivity to establish unified and mutually dependent global economy (Godil et al., 2021). Globalization has also supported tourism with enormous ramifications and encouraged it to become a major economic force (Razzaq et al., 2021b).

However, globalization leads to the high consumption of nonrenewable energy resources (Pata, 2021) and provides the platform for progressing to pollution-intensive industries. With global advancement, it is difficult the control environmental degradation without developing strong policies related to environmental sustainability (Kirikkaleli et al., 2021). However, with the environmental policy intervention and increased dissemination of new eco-friendly technology and business practices, globalization can reduce the carbon footprint (Sabir & Gorus, 2019; Saud et al., 2020).

As discussed earlier, globalization (GLB) leads toward the technology transformation of the industrial and business practices to improve ecological quality. For this purpose, this study also considers the technology innovation impact on the carbon footprint. Advanced economies seek new methods to reduce the dependency on fossil fuels in production and transportation (Bekun et al., 2019). The TOR provides accessibility to alternative or renewable energy resources, reduces production time, and provides better solutions to mitigate carbon emissions (Chen et al., 2021; Cheng et al., 2021; Destek & Manga, 2021). TOR is a critical factor in mitigating carbon emissions in developing countries (Shuai et al., 2017; Sinha et al., 2020; Wang et al., 2021). However, in developing countries, the TOR increases its ecological footprint due to the adaptation of imported technologies that are less eco-friendly (Chunling et al., 2021; Mushta et al., 2020).

There are several reasons to select the group of Ten (G-10) countries for the analysis, such as these countries have a common interest in economic growth. Moreover, the member's countries of the group are accounted to hold the major share of around 48% of the aggregate GDP of the world with the highest contribution of 24.08% of the USA (Worldometer, 2017). Furthermore, these countries have established better economic growth policies to support sustainable development due to economic,

financial, and monetary interests. According to the Global Footprint Network (2020), among 11 countries of G-10, only two countries, such as Canada and Sweden, have ecological reserves (biocapacity exceed footprint). In contrast, the remaining nine countries are ecologically deficient (footprint exceed biocapacity) countries. Therefore this group needs to pay more attention to reducing its ecological footprint.

As per our knowledge, not a single study has been carried out to analyze the integrated impact of TOR, GLB, INV on EF specifically for G-10 countries. The study covers the gap by using the CS-ARDL method to analyze the association among tourism, globalization, technology innovation and ecological footprint for the penal of G-10 countries. This method was first introduced by Chudik and Pesaran (2015) give some advantage over the other panel data estimators such as this method can tackle the issue of C-SD (cross-section dependency) in panel data analysis and provide robust results. Moreover, this method can be applied to the same or mixed order integrated series. Furthermore, due to the heterogeneous nature of the sample group of G-10 countries, this method is the most appropriate estimator to investigate the long-run and short-run associations. The outcomes of the study revealed that tourism and globalization are spurring the ecological footprint in G-10 countries, whereas technology innovation helps to reduce environmental degradation. These results will provide a better understanding to the policymakers of G-10 countries to control the ecological deficits.

The remaining part of the study covers the following sections: Sec. 2 provides the detailed literature review, whereas Sec. 3 describes the methodology with data description and methodological framework employed in the study. Section 4 consists of the estimations and their discussions while Sec. 5 presents the study's conclusion and suggests some policy implications.

## **2. Literature review**

Environmental sustainability becomes a key challenge that gets the researchers' growing concern and broadens the field of empirical research. The EF as a proxy of environmental quality has gained special attention. Numerous recent studies have addressed the factors which contribute to increasing/decreasing the size of ecological footprints, such as natural resources, economic growth, globalization, agriculture, tourism, human capital, and renewable energy resources (Ahmad et al., 2020; Ansari et al., 2021; Cheng et al., 2021; Chunling et al., 2021; Katircioglu, 2021; Nathaniel et al., 2021a, 2021b; Rehman et al., 2021; Yang et al., 2021a, 2021b; X. Yang et al., 2021). The brief literature related to the study variables is as follows.

### **2.1. Tourism industry and ecological footprint**

Tourism, as one of the fast-growing industries of the world, is an energy-intensive industry (Luo et al., 2020). Moreover, tourism is also held responsible for emitting extensive carbon emissions through various tourism-related activities (Xuefeng et al., 2021; Zhang & Liu, 2019).

A considerable amount of existing research has analyzed the effects of tourism on environmental sustainability by using ecological footprint with different empirical methods, and research approaches such as Godil et al. (2020) studied the link between TOR, FDI and EF. The study used the data series of Turkey from 1986 to 2018. The empirical finding demonstrates that the FDI, GLB, and TOR have a constructive influence on the EF. Similarly, Kongbuanai et al. (2020) study the impact of TOR and nonrenewable energy resources in the ASEAN countries over the period of 1995 to 2016. The findings of the Driscoll-Kraay panel regression method endorsed the positive relationship of tourism and nonrenewable energy resources with the EF (Sharif et al., 2020; Sun et al., 2022).

In the same vein, Ansari and Villanthenkodath (2021) assess the effect of tourism arrival and tourism receipt on the top tourism countries. The estimates of the NARDL approach have affirmed that the tourism arrivals increase the size of ecological footprint, whereas the tourism receipt plays an important role in reducing the EF. In addition, the analysis of tourism with respect to EF for top 10 destinations countries carried out by Alola et al. (2021) shows that during the period from 1995 to 2016, the development of the tourism industry has significantly enhanced the environmental degradation. Lee and Chen (2021) also endorse the positive correlation of TOR with environmental degradation. They applied the quantile regression approach to the panel data of 123 economies.

Moreover, Nathaniel et al. (2021a) studied the contribution of tourism toward ecological distortion by employing the CUP-FM and CUP-BC estimates for the panel data of the top ten tourist countries. The results of the study revealed that tourism growth (as tourist arrival and tourist receipt) positively affects the EF. Conversely, Katircioglu et al. (2018) explored the negative and significant relationship of TOR development with EF in top tourist countries. The increase of tourism activities improves the environmental quality. Similarly, Khan and Hou (2021) suggest the adverse impact of TOR on the EF for 38 IEA countries based on estimates obtained through the FMOLS approach for the time span from 1995 to 2018.

## **2.2. Globalization and ecological footprint**

Globalization plays an important role in environmental sustainability. In recent years, number of several researchers have investigated the impact of GLB on the EF to confirm whether globalization upsurge the size of EF or reduces the size of EF. For instance, Kirikkalieli et al. (2021) observe the effects of GLB on environmental degradation in Turkey for the period from 1970 to 2017 by applying the dual adjustment approach and found that globalization enhances the EF. Similarly, Adebayo and Acheampong (2021) use the quantile to quantile regression approach to explore the detrimental effects of globalization in Australia from 1970 to 2018. The study result revealed that the increase in globalization in Australia upsurges environmental degradation. Moreover, Rehman et al. (2021) examine the link of globalization with EF in Pakistan for the span of 1974–2017. The study has applied the linear ARDL method. The findings have confirmed that GLB enhances environmental deprivation in Pakistan.

Moreover, Sharif et al. (2019) found mixed results of the influence of GLB on EF. The empirical study for OEDC and non-OEDC countries shows the positive nexus between GLB and EF for Belgium, Sweden, Norway, the Netherlands, Denmark, Switzerland, Portugal, and Canada. The increased level of GLB enhances trading and manufacturing and leads to an increase in EF. Whereas in the case of France, Germany, the UK, and Hungary and the study report the negative relationship of GLB and EF. Similarly, Ahmed et al. (2021a) has also highlighted the mixed relationship of globalization with EF. Their study for the United States explores the impact of different dimensions of GLB, such as economic globalization contributes toward environmental degradation whereas social globalization reduces the EF.

On the other hand, the studies carried out by Zaidi et al. (2019) for ASEAN countries, and Saud et al. (2020) for one-belt-one-road countries endorsed the negative impact of GLB on EF. The result shows that GLB alters economic advancement and mitigates environmental deterioration. Correspondingly, Apaydin et al. (2021) study the environmental convergence phenomena for 130 countries to find the association among GLB and EF from 1980 to 2016. The results of CCEMG and AMG methods discovered that there is no significant impact of globalization on the EF. Similarly, a recent study by Ahmed et al. (2021b) employed the symmetric, and asymmetric methods of ARDL applied on the data from 1997 to 2016 to explore the link between economic GLB and EF in Japan. The outcomes of the study suggest that both the positive and negative changes in economic GLB reduce the size of EF.

### **2.3. Technology innovation and ecological footprint**

The role of TOR for environmental sustainability has been widely discussed in recent literature, and most of the studies found a negative association between INV and ecological footprint. (Ahmad et al., 2020; Cheng et al., 2021; Chunling et al., 2021; Ke et al., 2021; Khan et al., 2020; Kihomobo et al.2021; Rehman et al., 2021; Ulucak, 2020; Zhuang et al., 2021) .Ahmad et al. (2020) investigate the impact of technology innovation on the EF through the CS-ARDL method for the time span from 1984 to 2016 and found that TOR has a contrary effect on EF and elevates the emission of greenhouse gases in emerging economies. Similarly, Kihombo et al. (2021a) has employed the STIRPAT framework and analyzed the role of technology innovation to reduce carbon emission in West Asia and Middle East countries from 1990 to 2017. The results of the study endorse the positive association of technology innovation with the improvement of environmental quality. In addition, Yang et al. (2021a) also explore technology innovation's role in controlling environmental degradation. The study employed the advanced estimator of the second generation to evaluate the data of BICS (Brazil, India, China, and South Africa) countries for the period from 1990 to 2016. The finding of the study affirms the contribution of technology innovation to reducing the size of EF in BICS countries. Contrarily, Chunling et al. (2021) explore the opposite relationship for TOR and EP in Pakistan. The surprising outcome of the study disclosed that in developing countries, the TOR increase ecological footprint because the adaptation of imported technologies that are less eco-friendly.



### 3. Methodology

#### 3.1. Description and source of data

The aim of this study is to evaluate the impact of the tourism industry, globalization, and technology innovation on the ecological footprint in G-10 countries. The Group of (G-10) is eleven industrial countries with common economic interests consisting of Belgium, Canada, France, Germany, Italy, Netherland, Switzerland, the United Kingdom, and the United States of America. The logarithmic transformed annualized panel data was used from 1995 to 2019 in the study, which comprise of ecological footprint (EF) employed as a proxy of environmental degradation, international tourist arrival (TOR) as the tourism industry, technology innovation (INV) as the number of registered patents, KOF Globalization Index (GLB) as globalization, and gross domestic product as economic growth (GDP) of G-10 countries. KOF Index measured globalization in terms of foreign direct investment (FDI), flow of trade (actual) income outflow to foreign nationals, including taxes and other tariff rates. The summary of the variable is presented in Table 1.

#### 3.2. Methodological framework

The panel data can be subject to persuasive cross-sectional dependency (C-SD). Therefore, it is crucial to address the effect of some common unobserved factors or spillover effects influencing all the series, which may lead to spurious results if ignored before carrying out further estimates (Pesaran, 2004). Moreover, the identification of C-SD between series helps to select the appropriate unit root test (Tao et al., 2021). This study uses the Pesaran (2015) test to assess the presence of C-SD issue.

Moreover, to identify the stationarity of the panel, the study employed the widely used second-generation CIPS panel unit root test introduced by Pesaran (2007). This test is based on the average of the observed individual CADF and establishes the null hypothesis testing by considering the C-SD and residual serial correlation (Khan & Hou, 2021; Nathaniel et al., 2020).

The following step is to apply the cointegration test to assess the correlation among nonstationary time series in long run. The Westerlund (2007) test is an error correlation model (ECM) based cointegration test comprised of four cointegration tests Gt, Ga, Pa, and Pt. Among these four cointegration tests, the Gt and Ga test assume that cointegration is present at least in one panel data unit. In comparison,

**Table 1.** Variable's description.

Abbreviation	Variable description	Measurement	Source
<b>Dependent variable</b>			
EF	Ecological Footprint	Per Capita	GFN
<b>Independent variables</b>			
TOR	International Tourist Arrivals	Headcount	WDI
INV	Technology Innovation	Number of Patents	WDI
GLB	Globalization	KOF Globalization Index	WDI
GDP	Per capita income	USD Constant (2010)	WDI

Note: GFN and WDI denote Global Footprint network and World development indicators.

Data Source: <https://databank.worldbank.org/source/world-development-indicators>; <https://www.footprintnetwork.org/resources/data/>



the other two tests, such as Pa and Pt, support the presence of cointegration in the entire panel. Moreover, the Westerlund (2007) cointegration test also considers the potentially prevailed C-SD issue in the data (Kihombo et al., 2021b).

To evaluate the impact of tourism (TOR), globalization (GLB), technology innovation (INV), economic growth (GDP) on the ecological footprint (EF), the proposed general specific model is as under:

$$EF_{it} = f (TOR_{it}, GLB_{it}, INV_{it}, GDP_{it}) \tag{1}$$

The group of ten (G-10) countries is represented as *i* and the study span from 1995 to 2019 is demonstrated as *t* in the given Eq. (1). Further, the regression model has transformed from Eq. (1) is as under:

$$EF_{it} = \mu_{it} + \alpha_{1it} TOR_{it} + \alpha_{2it} GLB_{it} + \alpha_{3it} INV_{it} + \alpha_{3it} GDP_{it} + \gamma_i + \varepsilon_{it} \tag{2}$$

In the above Eq. (2), the intercept, regression parameters, cross-section term, and error term represented as  $\mu$ ,  $\alpha$ ,  $\gamma$ , and  $\varepsilon$ , respectively.

The study employed the CS-ARDL (cross-sectionally augmented autoregressive distributed lag) method of estimation presented by Chudik and Pesaran (2015). It is the most appropriate methodology to access the long-run association of variables in the presence of C-SD and slope heterogeneity. The CS-ARDL estimator extends the ARDL approach by considering the time dynamics and error terms' cross-sectional correlation. The initial ARDL model for the study is illustrated as under:

$$D_{it} = \sum_{i=0}^{Pd} \omega_{1it} D_{it-1} + \sum_{i=0}^{Pe} \omega_{2it} E_{it-1} + \varepsilon_{it} \tag{3}$$

where  $E_{it} = (TOR_{it} + GLB_{it} + INV_{it} + GDP_{it})$

The ARDL model extended into CS-ARDL model by taking the cross-section average to limit the effect of CS-D

$$D_{it} = \sum_{i=0}^{Pd} \omega_{1it} D_{it-1} + \sum_{i=0}^{Pe} \omega_{2it} E_{it-1} + \sum_{i=0}^{Pa} \omega_{3t} \bar{A}_{t-1} + \varepsilon_{it} \tag{4}$$

In Eq. (4)  $D_{it}$  is used as the dependent variable such as ecological footprint, while the lag value of EF is illustrated as  $D_{it-1}$ . In the same equation, the independent variables such as tourism (TOR), globalization (GLB), technology innovation (INV), economic growth (GDP) for G-10 countries refer as  $E_{it-1}$ . Whereas the  $\bar{A}$  in Eq. (4) is demonstrated as the average of all variables and Pd, Pe, and Pa, represent the variable lags.

$$\bar{A}_{t-1} = (\bar{D}_{it-1}, \bar{E}_{it-1})$$

The slope parameters of long-run estimates through the short-run slope parameters in CS-ARDL model. The long-run slope parameters and the mean group estimator are described in Eqs. (5) and (6).

$$\hat{\vartheta}_{CD-ARDL\ i} = \frac{\sum_{i=0}^{Pe} \hat{\omega}_{1it}}{1 = \sum_{i=0}^{Pe}} \hat{\omega}_{I\ i} \quad (5)$$

The mean group is referred as under

$$\hat{\vartheta}_{MG} = \frac{1}{N} \sum_{i=0}^N \hat{\vartheta}_i \quad (6)$$

The estimations of the short run coefficients are as under

$$\begin{aligned} \Delta D_{it} = & \vartheta_i (D_{it-1} - \vartheta_i E_{it-1}) - \sum_{i=1}^{Pd-1} \omega_{1it} \Delta_i D_{it-1} + \sum_{i=0}^{Pe} \omega_{2it} \Delta_i E_{it-1} \\ & + \sum_{i=0}^{Pa} \omega_{3t} \bar{A}_{t-1} + \varepsilon_{it} \end{aligned} \quad (7)$$

Where  $\Delta_i = t - (t - 1)$

$$\hat{T}_i = -(1 - \sum_{i=i}^{Pe} \hat{\omega}_{1i}) \quad (8)$$

$$\hat{\vartheta}_i = \frac{\sum_{i=0}^{Pe} \hat{\omega}_{1i}}{\hat{T}_i} \quad (9)$$

$$\hat{\vartheta}_{MG} = \frac{1}{N} \sum_{i=1}^N \hat{\vartheta}_i \quad (10)$$

The negative and significant value of ECM (-1) indicates the validity of the CS-ARDL estimates which represent long-run equilibrium adjustment and stability (Shen et al., 2021).

#### 4. Estimations and discussions

The world has become a global village (Ahmed et al., 2020). Technological advancement the rapid growth of industrialization has strengthened the factor of dependency across economies (Keser et al., 2021). Therefore the effects of any positive or negative tremors (unobserved common factor here) may be transmitted to other countries of the study. Thus identification of the C-SD issue in panel data is the primary and crucial step to avoid the spurious results of the further estimates. The panel data analysis starts with the test of Pesaran (2015) to evaluate the presence of C-SD. According to Table 2, the result of C-SD test shows that the probability values of C-SD test are significant at the significance level of 1% and fail to accept the null hypothesis of no C-SD. Thus the existence of C-SD in the selected panel data has been confirmed and required to apply the panel unit root test and panel cointegration estimator from second generation (Ahmed et al., 2020).

**Table 2.** Cross-sectional dependency and unit root tests.

Variables	CD test	P-value	CADF unit root test*	CIPS unit root test
EF	14.219	0.000	4.368***	3.654***
TOR	9.830	0.000	5.725***	6.103***
INV	15.745	0.000	3.967***	3.248***
GLB	12.120	0.000	6.310***	5.462***
GDP	18.902	0.000	4.540***	4.005***

Note: All variables are stationary at first difference in both unit root tests.

\*\*\*Level of significance at 1%.

Source: Author's source

**Table 3.** Panel cointegration (Westerlund, 2007).

Statistics	Values	Z-values	P-values
Gt	-8.512	-8.460	0.000
Ga	-5.210	6.322	0.000
Pt	-7.625	-7.514	0.000
Pa	-10.657	-10.890	0.000

Source: Author's source

**Table 4.** CS-ARDL analysis (long run CS-ARDL results).

	Beta value	t-statistics	Sig.
<b>DV: EF</b>			
TOR	0.097***	5.376	0.000
INV	-0.102***	-4.822	0.000
GLB	0.298***	6.750	0.000
GDP	0.530***	6.541	0.000

\*\*\*Level of significance at 1%.

Source: Author's source

For the unit root deduction in all variables, CADF and CIPS panel unit root tests are applied (refer [Table 2](#) for results). According to the outcomes, all the panel data series such as EF, TOR, INV, GLB, and GDP are stationary at the first difference and significantly reject the null hypothesis of unit root presence. Thus all the variables are integrated into order I(1).

Moreover, in order to evaluate the cointegration among variables of G-10 countries the Westerlund (2007) panel cointegration test has applied which also take into account the C-SD issue of panel data. The test results are reported in [Table 3](#) to demonstrate that the statistical group Gt and Ga and the panel group Pt and Pa have significant P-values and reject the null hypotheses of no cointegration. Thus the cointegration existence implies the long-run association of TOR, INV, GLB, and GDP with EF.

Further, after the confirmation of cointegration among variables, the CS-ARDL (Cross-sectionally augmented autoregressive distributed lags) test was employed by the study to investigate the long-run and short-run relationship of TOR, INV, GLB, and GDP with EF. [Table 4](#) demonstrates the outcomes of long-run CS-ARDL estimates.

According to the outcomes presented in [Table 4](#), the long-run coefficient of the TOR is 0.097 and highly significant. The positive coefficient demonstrates that the 1% increase in the TOR upsurges the ecological footprint of G-10 countries by 0.097% in the long run. The empirical finding of a positive association of TOR with EF endorses the results of Nathaniel et al. (2021a) and Kongbuamai et al. (2020). In contrast, these outcomes are contrary to the empirical finding of Khan and Hou (2021), who state that tourism reduces environmental degradation.

**Table 5.** CS-ARDL analysis (short run CS-ARDL results).

	Beta value	t-statistics	Sig.
<b>DV: EF</b>			
ECT	−0.405***	−3.755	0.000
TOR	0.050**	2.401	0.000
INV	−0.074**	−2.218	0.000
GLB	0.250***	4.635	0.000
GDP	0.480***	5.582	0.000

\*\*\*, \*\* & \* showing level of significance at 1, 5, and 10 percent, respectively.

Source: Author's source

Moreover, the technological innovation parameters illustrate the destructive effect on the ER; in the long run, the negative and significant value of the coefficient is  $-0.102$ , which indicates that the increase in INV by 1% decreases the EF by 0.102% long-run. The inverse relationship between INV and EF is in line with the existing studies of Adebayo and Odugbesan (2021) for Brazil, Khan et al. (2020), and Ahmad et al. (2020) for China, while inconstant with the study results of Chunling et al. (2021) for Pakistan. On the other hand, the long run CS-ARDL estimates give the positive and significant coefficient of 0.298 for GLB, demonstrating that the increase in globalization is the reason for EF enlargement in G-10 countries. These findings are consistent with the study result of Ahmed et al. (2021a) for the USA, Kirikkaleli et al. (2021), for Turkey and inconsistent with the study outcomes of Ahmed et al. (2021b) for Japan, and Apaydin et al. (2021) for 130 countries. Besides this, the GDP is also significantly and positively linked with ER in the long run with the coefficient value of 0.530. The activities related to economic growth increase the environmental deterioration (Lee & Chen, 2021).

Table 5 presents the short-run CS-ARDL estimates of the panel data. According to the outcomes, the TOR, INV, GLB, and GDP have the same associations with EF in the long run. However, the correlation significance has been reduced for TOR and INV. Whereas the coefficients value of short-run estimates of TOR, INV, GLB, and GDP are 0.05,  $-0.074$ , 0.250, and 0.480, respectively, show the intensity of the impact of these variables on EF. Finally, the value of ECM (error correction model) illustrates as  $-0.405$  in Table 5 which is negative and significant and indicates a casual long-run relationship among variables and reasonable convergence toward equilibrium.

## 5. Conclusion

The increased size of the ecological footprint is an alarming situation for the world. Several studies have highlighted the factors that contribute to increasing environmental deterioration. This study has taken the initiative to evaluate the aggregate impact of tourism, globalization, and technology innovation on the ecological footprint of G 10 countries for the time span over 1995 to 2019. The C-SD test (Pesaran, 2015) has confirmed the C-SD issue present in the study data. In contrast, the unit root existence examined by the CIPS panel unit root test introduced by Pesaran (2007). The panel data for all variables are found to be stationary at the first difference, which has motivated to use the Westerlund (2007) panel cointegration test, which has shown that the cointegration exists between TOR, GLB, INV, and EF.

Moreover, the results of the CS-ARDL test illustrate the significant and positive correlation of TOR, GLB, and GDP with EF. In comparison, the outcome shows a significant negative correlation of INV with EF. The positive association of tourism with the ecological footprint is plausible because tourism growth requires more investment. High tourism activities are responsible for excessive fossil fuel consumption, loss of natural habitat, and more carbon emissions. Thus, in the long run, tourism's contribution increases the ecological footprint in G-10 countries. Similarly, the increase in globalization also tends to increase the trade activities and excessive use of fossil fuel which leads to an increase in the size of EF.

On the other hand, according to this study's empirical finding, the INV and EF negative association for G-10 countries is also justifiable as TOR is considered a sustainable development tool in all developed economies and promotes renewable energy resources consumption, thus mitigating carbon emission and reducing the EF.

Based on the empirical findings to control the environmental impact of tourism and globalization it has been suggested that the policymakers should implement a few new policies to support tourism and globalization without compromising the sustainability of the environment. Moreover, few initiatives can be taken on an urgent basis in G-10 countries which are free from financial constraints. Such as, the tourism industry should carefully handle the natural resources and encourage the use of renewable energy resources. For instance, the use of electric vehicles for domestic tourism transportation encourages eco-friendly activities and implement comprehensive tourism policies and practices to protect the environment. Moreover, the increase in capital investment for domestic tourism helps the industry to change the energy consumption patterns and limit the carbon emission of this sector.

On the other side, to reduce the impact of globalization, policymakers need to consider both the economic and social aspects that enhance environmental issues. Furthermore, there is a need to create awareness at the industry level to save natural resources. High investment in R&D related to TOR will help to find new ways to get more output with less input of energy resources. The investment in technology innovation to reduce the carbon footprint of the high ecological deficit countries of the group such as Belgium, Japan, Netherland, Italy, Germany, Switzerland, and the United Kingdom should be supported collectively by all group members through offering incentives and subsidies. Here the exchange of resources and knowledge can also help to reduce the overall EF.

This study has investigated the impact of TOR, INV, and GLB on EF in G-10 countries and limited the analysis to the long-run and short-run causal estimates. However, future studies can include more social, political, and economic variables such as human capital, industrialization, agriculture, etc. This can make the study more comprehensive. Moreover, in a future study, the use of the quantile regression approach provides in-depth knowledge of variable associations.

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