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ARTICLE

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Economic globalization and ecological impact in emerging economies in the post-COP21 agreement: A panel econometrics approach

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Abstract

Globally, the need for ecological well-being and sustainable development attracted research and policy attention over the years. However, issues concerning the nexus between globalization and ecological safety remain contentious and unresolved. Therefore, this study contributes to the discourse by evaluating the impact of economic globalization on ecological footprints in seven emerging economies (E7) while accounting for other drivers of environmental degradation in the outlined bloc for the period of 1990–2021. The present study leverages on panel data econometric techniques to achieve the study objectives. The findings shows that economic globalization and increase in economic activities drive a higher ecological footprint and thus reduce environmental quality in emerging economies. This study concludes that the economic progress of emerging economies and the increasing wave of their economic integration is detrimental to environmentally sustainable development. Therefore, this study recommends, among other insightful policy inferences, that the global agenda on sustainable development should be prioritized, environment-friendly integration among emerging economies should be pursued.

Environmental regulations should be strictly observed by the countries in their bid for economic development and integration.

KEYWORDS
climate change, ecological footprint, emerging economies, environmental sustainability, globalization, panel econometrics

1 | INTRODUCTION

Intensive industrialization over the years exacerbates ecological consequences emanating from human anthropogenic activities such as increased energy consumption especially from fossil fuel-based sources, globalization, among others (Alhassan et al., 2020; Udemba et al., 2023). Therefore, there is an increase in the evaluation of the eco-effect of these consequences, particularly energy consumption with much consideration of macroeconomic factors as outlined by the study of Shahbaz et al (2022). One of the most destructive effects of ecological destruction is the phenomenon known as global warming, which has posed unprecedented challenges for the continued existence and development of humanity. These challenges include severe weather problems, the extinction of species, and food shortages (Alhassan et al., 2020; Dong et al., 2019; Dong, Sun, & Dong, 2018). The sustainability and development of human ecology depend on natural resources, increased biodiversity, and food security, which are threatened by global warming and climate change (Dong, Sun, Li, & Liao, 2018). Thus, economic activities tend to aggravate ecological damages, which threatens the survival the entire ecosystem including the humankind.

To address the negative consequences of climate change and the phenomenon of global warming, the Paris Accord adopted during the Paris Conference of Parties in December 2015 (COP21) established a primary objective of restraining the increase in global temperatures to less than 2 degrees Celsius, with a specific aim of limiting it to 1.5 degrees Celsius above pre-industrial levels by the conclusion of 2020 (Pachauri et al., 2014). To achieve this target, greenhouse gas emissions must peak by 2025 and reduce by 43% at the end of 2030 (Rogelj et al., 2016). Thus, to achieve the targets and ensure environmental sustainability, it became imperative to evaluate pollution trends and determinants through a territorial lens to formulate effective strategies for dealing with the larger issue of carbon emissions (Dong et al., 2019; Wu et al., 2019).

Consequently, globalization emerges as a pertinent topic for discussion among scholars and policy makers in the contemporary societies. The recent intensive investments and financing of industries remain significant factors for examining economic globalization. The growth in economic globalization has rapidly eased the exchange of goods, resources, and information asymmetry between countries (Lee et al., 2015). As a result, economies worldwide have opened their markets by deliberately curtailing trade barriers. The gradual rise in countries' openness to global economic practices leads to ecological deterioration (Destek & Sarkodie, 2019). Hence, several studies have considered the drivers of environmental sustainability and ecological footprint (Bekun, 2024; Bilgili & Ulucak, 2018a; Lin et al., 2018; Ozcan et al., 2018, 2019; Solarin, 2019; Solarin & Al-mulali, 2018; Ulucak & Lin, 2017). However, there is paucity of documentation in the extant literature on the theme on globalization on ecological footprint, particularly in emerging economies (Hossain et al., 2022).

Several countries have now observed a big environmental overshoot, as human's resource consumption is indeed exceeding the earth's capability to regenerate those resources. Approximately 80% of the world's citizens live in a region with an economic deficiency. Nations encounter ecological deficiency, as consumer needs are overproduced by suppliers which over generated ECF in the world. Moreover, nearly 70% of the world's GDP is below the norm and thus lives based on excessive usage. As ecological limits become more constrained, a nation's success is intricately tied to its ability to maintain sustainability within those limits (Global Footprint Network, 2018). Yet, many nations switch to commerce, and energy production, which contributes to releasing more pollution into the environment.

The ineffective employment of natural assets diminishes the number of natural resources available for each region and increases the ecological footprint per capita (ECF) and leads to environmental degradation. The use of natural resources is inefficient. The extraction of natural resources increases due to accelerated economic activity and poses significant environmental challenges (Danish, Baloch, et al., 2019). The shift from obsolete techniques to advanced production systems, such as recycling, manufacturing, creative processes, and value-adding to goods among others, to replace natural resources exploitation, may boost environmental quality. Thus, the need to examine the causative linkage amid real GDP, total natural resources rent, economic globalization, and ECF has become crucial (Hossain et al., 2022).

Therefore, this study evaluates the economic globalization-ecological footprint nexus in the developing economies—nations in E7 (Brazil, Russia, India, Indonesia, Mexico, Turkey, and China) controlling for real GDP, sustainable energy usage, and revenue generated from natural resources, that is, natural resource rents. The choice of emerging economies (E7) in this study hinges on the rapid economic growth the countries are recording and the increase in their importance in the global economy. For instance, the Economic projections of the International Monetary Fund (IMF) indicate that, by 2050, the E7 member states could contribute about 50% of the global economic output, and their economic strength GDP will grow a little over 20% (IMF, 2023). In comparison with the concept of real exchange rate equality, Republic of China has presently exceeded the average economic status of the United States as of 2050. In the same vein, there is a possibility that India may potentially become the world's third largest economy, surpassing the United States (Celik et al., 2023; IMF, 2023; Nam, 2022). Projections concerning the PPP of global economies suggest that the United Kingdom is anticipated to descend to the tenth position, and France is also expected to drop out of the top 10. By contrast, Indonesia is predicted to rise to the fourth position, and several emerging markets like Indonesia, Brazil, and Mexico may potentially surpass the economic standings of the UK and France. Furthermore, countries such as Egypt and Pakistan could outperform Italy and Canada in respect of their economic activity volumes (IMF, 2023). The IMF report also foresees that Vietnam, India, and Bangladesh may emerge as the fastest-growing economies from 2015 to 2050, with average annual growth rates hovering around 5%. These shifts in economic dynamics suggest that the impact of developed economies over emerging markets, particularly in Asian continent and beyond, is poised for transformation.

The advantage of economic growth is that it facilitates industrialization, which also causes the depletion of natural resources. However, the exploitation of natural resource deposits negatively impacts the environment (Danish, Hassan, et al., 2019). Allied with the rise in economic revenue is the potential consequence of decreased biocapacity and increased ecological footprints—ECF, hereafter (Panayotou, 1993) emanating from intensified production using natural resources. Some prior studies (see, Danish, Baloch, et al., 2019; Solarin & Al-mulali, 2018; Islam et al., 2022) highlighted that ECF is a good proxy for environmental deterioration. ECF has also been utilized as a degree of environmental contamination in the certain current research literature (Aydin et al., 2019; Bello et al., 2018; Destek et al., 2018; Ozcan et al., 2019; Sarkodie & Strezov, 2018; Ulucak & Apergis, 2018). These studies are evidence that increased economic development increases the exploitation of natural resources. Given that, increased exploitation of natural resources may increase environmental degradation (Danish, Baloch, et al., 2019; Ulucak & Bilgili, 2018; Waheed et al., 2018), contrary reports are indicating that exploitation of natural resources reduces carbon impact (Panayotou, 1993). This means that if environmental management practices are integrated into the utilization of natural resources, or if renewable energy generation is permitted, exploitation of natural resources may cause minimal ecological damage. Contemporary energy sources like coal, petroleum, and natural gas are employed for power generation in emerging economies. This coal, oil, and gas were in place to fulfill imports of fossil fuel (Ansari et al., 2022). However, renewables are rich and green and conventional fuels are wasteful and lead to ECF (Owusu & Asumadu-Sarkodie, 2016). Unfortunately, globalization enhances the need for more mobility, which encourages the use of fossil fuels and the subsequent ECF generation. For instance, Danish and Wang (2019) conceive that increased economic growth generates more wealth, which affects human safety and natural resources exploitation. Also, therefore, this study different from extant studies in several. First, it emerges as one of the pioneering efforts in the exploration of the economic globalization-ECF nexus for emerging economies (E7 nation). The focus to the E7 countries because carbon intensity is a crucial issue, which has been at the center of most political and round-table discussions of the member states. Secondly, this study used ecological footprint, which is a comprehensive measure of environmental degradation, and it offers valuable considerations to other control variables such as natural resource rent, environmental growth, and renewable energy. The ECF is a measurable metric of the environmental degradation driven by the bio-producing land and water use of individuals and communities (Danish, Hassan, et al., 2019; Ulucak & Bilgili, 2018). It is also considered a determinant of human-induced carbon footprint (Ulucak & Bilgili, 2018). The ECF will be required to examine and monitor the use of capital in the world and measures the viability of the living patterns, and production activities of industries, cities, regions, and nations. The EFC has mainly been used to promote environmental estimation, specifically, as a method to assess the sustainability of a nation (Solarin et al., 2019). Thus, this study provides insights into the primary aspects influencing the accomplishments of sustainable development goals in light of decreasing ECF in E7 nations and beyond. Thirdly, this analysis presents a robust approach to panel analysis estimation including structural breaks tests, which would produce estimations that are more accurate for policy formulation in the study blocs. Hence, the novelty contributions of this study include the consideration of economic globalization, the application of the E7 sample (the fastest-growing economies with projected high levels of ecological degradation), the use of comprehensive measure of environmental quality, and the employment of robust panel data statistical techniques.

The rest of this study is presented as follows: Section 2 renders the review of related literature on the theme under consideration. While Section 3 focuses on the data and econometric methodology, Section 4 is devoted to the results and discussion of empirical findings. Section 5 presents the concluding remarks and policy suggestions on the study.

2 | REVIEW OF RELATED LITERATURE

Theoretically, several channels that link globalization and environment have been identified (Panayotou, 2000). First, the theoretical literature postulates that globalization promotes economic growth through the expansion of trade and economic activities. Thus, the attendant consequences of economic growth on environment are propelled by globalization. The second channel is through diffusion of capital and technology. The third channel is that globalization accelerates structural change. This leads to changes in industrial structures, and thus resource use and levels of environmental pollution and degradation. Also, globalization transmits and magnifies policy distortions and market failures, and lastly, generates pressure for economic and non-economic reforms. These channels are discussed under the premises of the Environmental Kuznets Curve (EKC) hypothesis (Alyahyan, 2007; Caviglia-Harris et al., 2009) pollution hallo and haven hypotheses (Balsalobre-Lorente et al., 2019), as well as the ecological modernization theory (York et al., 2010), Therefore, cumulatively, these theoretical postulations provide the theoretical underpinning of this study.

Empirically, the global focus on environmental safety and ecological well-being has sparked an urgency for the environmental agenda from different contexts. Hence, environmental sustainability in this context has evolved into a crucial worldwide factor influencing development (Bilgili & Ulucak, 2018; Bilgili & Ulucak, 2020). Although there exist three pillars of sustainable growth, environmental safety among these elements emerges as the most considered among the trio because climate change is worsening under poor environmental management (Ulucak et al., 2019). Due to its importance as a depleting factor, researchers have explored ECF from various angles. For instance, a strand of literature has studied the income influence on ECF with other theoretical factors (Ozcan et al., 2018, 2019). Aşici and Acar (2016) explored how ECF migrates income in 166 states between 2004 and 2008. They claim that their study shows a U-shaped connection between GDP growth and ECF.

Similarly, Uddin et al. (2017) explored the linkage between earnings and ECF in the 27 nations with the high pollution levels. They found that ECF had a favorable impact on revenue income when using the Dynamic Ordinary Least Square (DOLS) method. This represents that a surge in ECF is associated with an increase in income. Wang et al. (2020), on the other, found that economic progress generally had a positive effect on ECF using an AMG (augmented mean Group) methodology on data from 14 African states.

The environmental Kuznet curve (EKC) effect has also been investigated across several European countries (Destek et al., 2018), mainly using macroeconomic approaches with second-generation panels. Inferring from the U-shaped correlation established between income and ECF, similar associations established with variables like non-renewable energy and ECF show deterioration of the atmosphere emanates from commercial activities. Ozcan et al. (2018) tested the EKC theory, with evidence from Turkey with an observational analysis using the bootstrap rolling frame. The results demonstrated the theory of the EKC for Turkey is therefore not verified. Destek and Sarkodie (2019) investigated the EKC in an ECF study. They investigated the influence of financial development and energy usage in 11 recently industrialized economies. The EKC theory was confirmed by the AMG estimation method in their study. In essence, energy usage reduces ECF, whereas monetary use leads to surge in ECFs. Sarkodie (2018), however, uncovered a U-shaped relationship in 17 African nations while examining the connection between income and environmental pollution. Besides, in 14 Asian economies Development and ECF are interdependent, according to Uddin et al. (2019). The Environmental Kuznets Curve (EKC) is supported in several nations, such as India, Nepal, Malaysia, and Pakistan. Aydin et al. (2019) noted that the Environmental Kuznets Curve (EKC) did not exhibit a Smooth Transition (PSTR) pattern across a dataset spanning 26 EU countries from 1990 to 2013. In a separate analysis of additional EU countries, Destek et al. (2018) identified a U-shaped relationship between sales and Environmental Carrying Factor (ECF). Danish and Wang (2019) conducted research on Pakistan, examining the relationship between economic development and ECF, considering both biocapacity and human resources. Their study found a significant link between economic development, represented by biocapacity, and an increase in ECF, while an appreciation of human capital had the opposite effect, reducing ECF. Çetin and Saygın (2019) equally confirms the EKC hypothesis for the Turkish economy. In addition Ozturk et al. (2022) revealed that shocks on income inequality increases carbon emissions in Turkey.

The nexus between economic progress and environmental degradation has been attributed to the heavy consumption of fossil fuels and natural resources (Sarwar et al., 2021). Thus, Ramzan et al. (2024) submits that the consumption of geothermal and nuclear energy sources improves environmental quality. Similarly, Aziz et al. (2023) and Cui et al. (2023) separately posits that transition to renewable energy will reduce ecological damage. The nexus between trade openness and environmental pollution has also attracted substantial research attention. Ertugrul et al. (2016) leaned on the pollution haven hypothesis and confirms that trade openness increases global carbon emissions. Contrarily, Cetin et al. (2015) used first-generation panel data analysis techniques with a global panel of countries. The study submits that trade openness enables diffusion of an improved technology and thus reduces environmental degradation (pollution halo).

Furthermore, urbanization was identified as a fundamental driver of environmental pollution. For instance, Çetin and Ecevit (2015); Cetin et al. (2018), and Çetin et al. (2023) submit that urbanization propels environmental degradation by increasing the level of carbon emissions. Tourism is equally identified as a determinant of environmental pollution across the world (Çetin et al., 2021). In line with the empirical evaluation of the capital diffusion channel, the linkage between financial development and environmental quality has been explored. Cetin and Ecevit (2017) and Çetin et al. (2022) reported that financial development reduces environmental degradation. Demir et al. (2023) also reported a causal nexus between health expenditure and environmental quality.

In terms of economic activities, agriculture is extensively link to ecological damage (see Çetin et al., 2020; Waheed et al., 2018). Evidence also exists to suggest that non-economic development factors account for rising and declining ECF. Charfeddine (2017), for instance, studied the consequences and profits of power usage on ECF and discovered that surge in energy demand leads to increased ECF. Bello et al. (2018) also showed that hydropower utilization decreased ECF in an emerging market and found an inverted U-fit shape relative to financial development and ECF. As such, financial growth among economies positively influences ECF generation.

The argument is expanded upon by Hassan et al. (2019) to consider how the utilization of natural resources affects ECF. They found that with the rise in the consumption pattern of natural resources, ECF also rises, based on information from Pakistan. Similarly, coal and oil consumption were found to be fundamental drivers of carbon emissions (Sarwar et al., 2019).

Foreign direct investment is also linked to environmental sustainability. For instance, Solarin and Al-mulali (2018) evaluated how foreign direct investment (FDI) affected ECF in 20 different nations. In contrast to impoverished countries, FDI to developed countries lowered ECF, according to Solarin and Al-mulali's (2018) findings. Moreover, in MINT nations, Balsalobre-Lorente et al. (2019) used the pollution heaven concept as an ecological deterioration measure for ECF. Their results suggest that FDI and ECF have an inverse U-shaping connection and support the theory of the EKC. Seker et al. (2015) also supports the positive nexus between FDI and environmental quality.

Rudolph and Figge (2017) also assessed the influence of globalization activities from different aspects—consumption, produce, import, and exportation. Relative to ECF creation in emerging economies, Danish and Wang (2019) recently presented a conceptual creativity strategy. Danish and Wang (2019) explored income-urban experiences and their effect on ECF. The report showed that urbanization in developing countries continues to decline with a rise in wages. Lei et al. (2021) add to current reports, by supplying new evidence on the effects of G7 pollution on economic globalization and financial development. Regarding the short- and long-term effects of the analysis, this current study employs new econometric methods such as CS-ARDL.

However, the analysis of economic effectiveness and power utilization for ECF remains unresolved. Specific attention has not been given to environmental effect of economic globalization in the emerging economies. The few studies that considered globalization-environment nexus focused on aggregate globalization index. Meanwhile, political, social, and economic globalization might have different impact on the environment. Also, it becomes difficult, if not impossible to develop and implement targeted policies concerning the globalization-environment relationship if the aggregate index of globalization is used. Consequently, due to the differing economic models and ecological regulations between nations, the unique nature of such actions contributes to the accordance between multiple nations regarding ECF indicators. The actual evidence provided in this report helps devise environmental legislation. Considering the above reasons, the goal is to find out the determinants of ECF in the E7 countries employing innovative development approaches, including renewable energies, economic growth, agricultural value-added, and natural resources. The period for E7 nations dependent on limited data in this analysis is limited from 1990 until 2021. The present study contributes to the most recent body of research by focusing on ecological footprint (ECF) instead of carbon dioxide emissions, as the E7 economies are presently addressing environmental issues associated with shortfalls.

3 | DATA AND METHODS

3.1 | Characterization of variables under consideration

The present work employs the use yearly frequency dataset from the World Bank database (WDI) to examine the connection between the study variables as outlined in Table 1 over the period 1990–2021. The choice of the period is determined by the limited availability of the data till 2021. For this context, the E7 economies (Brazil, Russia, India, Indonesia, Mexico, Turkey, and China) constitute the focus of this study. The present study will leverage on the use of the following variables to operationalize the study objectives. The variables include real GDPC, renewable energy usage proxied by renewable energy consumption (% of total final energy consumption), economic globalization, natural resource rents, electricity produced from non-clean sources, and the ecological footprint. Agriculture value-added

TABLE 1 Variables description and unit of measurement.

Variables	Acronym	Unit	Source
GDP per capita	GDPC	Constant 2015 US$	WDI
Agriculture value-added	AGA	Constant 2015 US$	WDI
Renewable energy	CE	Renewable energy consumption (% of total final energy consumption	WDI
Economic Globalization	ECG	KOF Globalization Index	Gygli et al. (2019)
Total natural resources rents	TNR	% of GDP	WDI
Electricity generation from non-clean sources (% of total)	EGN	% of total	WDI
Ecological footprint	ECF	Global hectare of farmland and carbon footprint	GFN

Note: WDI = Word Bank Development Indicator (2022) database while GFN = Global Footprint Network 2020 database.
Source: author's compilation.

(AGA) and gross domestic product per person (GDPC) are both expressed in constant 2010 US dollars. On the other side, renewable energy consumption was designated as CE and represented as a percentage of aggregate final energy usage, Economic Globalization (KOF globalization Index) was also denoted by ECG, Ecological footprint (global hectares per capita) is signified by ECF, together with total natural resource rents (% of GDP), oil, gas, and coal-based electricity generation (% of total). Table 1 provides the description, unit of measurement, and data sources.

3.2 | Model and methods

The analysis considers a carbon-income function while controlling for the role of renewable energy consumption, agriculture value-added, and energy consumption from non-clean sources within the framework of E7 economies while investigating the linkage between real GDP, total natural resource rent, economic globalization, and ecological footprint. To further the extant literature on the theme, the present study focuses on the relationship between our study variables for E7 countries. First, the E7 countries, which are outpaced by the G7 alone. The G7 economies are accountable for the second highest contribution to global economic integration. Understanding how large-scale economic activity and emissions are related would thus be very helpful in the global effort to reduce emission and achieve the UN-SDGs. However, the E7 nations account for a significant portion of the ecological footprint left by the world, thus it is important to comprehend the causes of such large emissions to reduce them, which would enhance the environment and make it better to live in. The study expands on previous research by integrating economic globalization and energy consumption from non-clean sources (Danish, Hassan, et al., 2019). Additionally, throughout the research period, several important policy meetings about the environment were taking place, including the Kyoto Protocol, the 2009 Inaugural Copenhagen Climate Summit, and its follow-up conferences. Thus, makes it possible for this study to evaluate how well the meeting's decisions are being put into practice in terms of lowering emissions level and thereby decreasing global warming in the E7 bloc. The empirical mode for this analysis was developed as:

$$\mathrm{LnECF} = \mathrm{f}\,(\mathrm{LnECG, LnGDPC, LnAGA, LnCE, LnTNR, LnEGN}) \tag{1}$$

$$LnECF_{2it} = \alpha_0 + \beta_1 LnECG_{it} + \beta_2 LnGDPC_{it} + \beta_3 LnAGA_{it} + \beta_4 LnCE_{it} + \beta_5 LnTNR_{it} + \beta_6 LnEGN_{it} + \varepsilon_{it} \tag{2}$$

To confirm that the research variables' adjustment remained unchanged throughout the series, variables underwent a logarithmic transformation, where LnECF, LnECG, LnGDPC, LnAGA, LnCE, LnTNR, and LnEGN are log alterations of the coefficients where εit, α, and β's represent the stochastic, interrupt, as well as the incomplete slope variables. The cross-sectional dependence (CSD) technique was used to ascertain if to use the first- or second-generation regression approach. When the CD technique is not carried out, the investigation becomes insufficient, unreliable, and worthless (Belaid et al. 2021). For the goal of determining robustness, the analysis employed the Pesaran (2007) CD technique. This technique uses the null assumption that cross-sectional dependency will not be obtained, where the following equation is used:

$$CD_p = \left(\frac{1}{N(N-1)}\right)^{\frac{1}{2}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij}\widehat{\gamma}_{ij} \rightarrow N(0.1). \tag{3}$$

Therefore, three estimating methods—FMOLS, DOLS, as well as the PMG-ARDL by Pedroni (2004), Pedroni (2001), and Kao and Chiang (2001)—are each used in this investigation. Notably, while the DOLS may account for the connection between the stochastic component and the outcome variable, it also introduces lags for the explanatory coefficients. To determine the stationarity qualities of the described coefficients as well as prevent the trap of a false analysis, the unit root technique of the coefficients before the estimate relationship estimation. The CD test, which is used in this study, is backed by first-generation panel unit roots (Nathaniel & Khan, 2020; Nathaniel et al, 2019). The DOLS is assessed by exploring Equation 4, which is shown as:

$$LnECF_{it} = \mu_i + x_{i,t}\Psi_{i,t} + \sum_{j=-p}^{p} \beta_j LnECF_{i.t-j} + \sum_{j=-q0}^{q0} p_{1.j} LnECGLnGDPCLnECLnTRN_{i.t-j} + p_{2.j} \sum_{j=-q1}^{q1} LnEGN_{i.t-j} \tag{4}$$

$$+ p_{3.j} \sum_{j=-q2}^{q2} LnGDPC_{i.t-j} + \varepsilon_{it},$$

p and *q* are the number of leads/lags. The FMOLS equation, which is stated as, estimates the long-term connection:

$$\text{LnE} = \mu_i + x_{i.t}\psi + v_{it} \tag{5}$$

$$x_{i.t} = x_{i.t} + \mathfrak{C}_{i.t},$$

where as x is a 5*1 vector of regressors, μ_i represents the divert, whereas $\mathfrak{C}_{i.t}$ and v_{it} are the error terms. Nevertheless, the appraisal of ψ is stated as:

$$\widehat{\psi}_{FMOLS} = \left(\sum_{i=1}^{N}\sum_{t=1}^{T}(x_{i.t} - \overline{x}_{i.t}) * (x_{i.t} - \overline{x}_{i.t})'\right)^{-1} * \left(\sum_{i=1}^{N}\left(\sum_{t=1}^{T}(x_{i.t} - \overline{x}_{i.t}) * \widehat{LnECF}_{it} - T\widehat{\Delta}_{v\mathfrak{C}}\right)\right) \tag{6}$$

Using the Pesaran (2015) technique, this study also looked at projections for the short- and long-term. In the (ARDL: p, q) structure, which incorporates all pollutant lags with regressors, the study moved on with the analysis of the connection between AGA, GDPC, ECG, CE, TNR, EGN, and ECF stated in Equation (1), given that:

$$LnECF_{it} = \beta_i + \sum_{j=1}^{p} \delta_{ij} LnECF_{it-j} + \sum_{j=0}^{q} \varphi_{i,j} Z_{it-j} + \varepsilon_{it} \tag{7}$$

where the explanatory variables utilized in this study are represented by this function; $Z_{it} = (LnECG_{it,}\ LnGDPC_{it,}\ LnAGA_{it,}\ LnCE_{it,}\ LnTNR_{it,}\ LnEGN_{it})$. βi designates the nation-level fixed outcomes, δij designates the slope of the lag pollutants vector where φi,j designates the slope of lag explanatory coefficients.

4 | RESULTS AND DISCUSSIONS

4.1 | Preliminary analysis

In the first place, the movement trends of the variables of interest, both upward and downward, are given in the Appendix A section: Figure A1. This is to provide a basis for the behavior of these macroeconomic indicators. Subsequently, the study provides a summary statistic of the variables under investigation. The Jarque-Bera test indicates that the data series exhibits a normal distribution, although except for ecological footprint and economic growth, all other variables under consideration were negatively skewed. The data shown in Table 2 indicate that economic growth displayed the highest mean value of 27.5476, with a range of values between 26.3216 and 29.9336. On the contrary, natural resources rent exhibited the lowest mean value of 1.0974, with a range of values between −1.9681 and 3.0908.

Subsequently, we proceed to explore the correlation analysis, in the correlation matrix that is presented in Table 3, it is shown that the consumption of renewable energy and by agriculture value-added as independent variables establish negative relationships with ecological footprint, which is the dependent variable. On the contrary, other independent variables showed positive relationships with ecological footprint.

4.2 | Findings of the cross-sectional dependence, stationarity, structural breaks, and cointegration tests

The outcome of the CSD technique shown in Table 4 illustrates no rejection of the null assumption for a lack of CD. For subsequent analysis, the study employs a first-generation panel estimation method. This is appropriate because the cross-sectional dependence test, as reported in Table 4, indicated absence of cross-sectional dependence. The outcomes of ADF and PP stationarity tests shows that all the variables are not stationary at level but stationary at first difference. We also used the used Karavias and Tzavalis (2014) panel unit root test with two

TABLE 2 Basic summary statistics.

	LnECF	LnECG	LnTNR	LnGDPC	LnCE	LnAGA	LnEGN
Mean	1.6704	4.0389	1.0974	27.5857	2.9792	2.1809	4.3142
Median	1.1059	4.0888	1.2872	27.5476	3.1864	2.1922	4.4008
Maximum	4.2397	4.2771	3.0908	29.9336	4.0716	3.3200	4.5368
Minimum	−0.2204	3.4662	−1.9681	26.3216	1.1724	1.0736	3.9360
Std. Dev.	1.5784	0.1718	1.1534	0.7238	0.8854	0.6613	0.1950
Skewness	0.5047	−1.0569	−0.7479	0.9955	−0.6743	−0.0540	−0.5186
Kurtosis	1.6586	3.8688	2.9954	4.4884	2.3355	1.6955	1.6920
Jarque-Bera	21.371	39.6136	16.9696	46.8671	17.1431	12.9926	21.1323
Prob.	0.0000	0.0000	0.0002	0.0000	0.0001	0.0015	0.0000
Sum	304.0255	735.0931	199.7436	5020.613	542.2249	396.9331	785.1897
Sum Sq. Dev.	450.9411	5.3465	240.8232	94.8478	141.911	79.1734	6.8886

TABLE 3 Correlation analysis.

Coefficients	LnECF	LnECG	LnTNR	LnGDPC	LnCE	LnAGA	LnEGN
LnECF	1						
Prob.	–						
LnECG	0.3280[a]	1					
Prob.	(0.0000)	–					
LnTNR	0.2392[a]	−0.1512[b]	1				
Prob.	(0.0011)	(0.0089)	–				
LnGDPC	0.4429[a]	0.2782[a]	0.2466[a]	1			
Prob.	(0.0000)	(0.0000)	(0.0602)	–			
LnCE	−0.6292[a]	−0.5005[a]	−0.2361[a]	−0.1448[a]	1		
Prob.	(0.0000)	(0.0000)	(0.0015)	(0.0000)	–		
LnAGA	−0.1458[a]	−0.5034[a]	−0.1193[a]	−0.1949[a]	0.5852[a]	1	
Prob.	(0.0000)	(0.0000)	(0.9122)	(0.0000)	(0.0000)	–	
LnEGN	0.6015[a]	0.4758	−0.0554	0.1637[a]	−0.8514[a]	−0.3480[a]	1
Prob.	(0.0000)	(0.8760)	(0.2807)	(0.0000)	(0.0000)	(0.0039)	–

Note: ([a,b], and [c]) represent statistical rejection level at 0.01, 0.05, and 0.10 level, respectively.

TABLE 4 Cross-sectional dependency (CSD) and structural break tests.

Pesaran (2007) CD test				
Model		**Test statistic**		***p*-value**
LnECF = f(LnECG, LnTNR, LnGDPC, LnCE, LnAGA, LnEGN)		5.0601		(.1800)
Ditzen, Karavias & Westerlund (2021) Sequential test for multiple breaks				
		Bai & Perron Critical Values		
	Test statistic	**1%**	**5%**	**10%**
F(10)	13.36	4.08	3.35	2.99
F(21)	5.03	4.32	3.69	3.34
F(32)	0.94	4.51	3.84	3.53
F(43)	−0.38	4.59	3.96	3.68
F(54)	−0.95	4.70	4.07	3.77
Detected number of breaks		2	2	2
Estimation of break points				

Number	Index	Date	95% Confidence interval	
1	9	1998	1997	1999
2	22	2011	2010	2012

(2) structural breaks for robustness check of the stationarity properties of the variables. The two (2) were identified (1998 and 2011) by the Ditzen, Karavias and Westerlund (2021). Sequential test for multiple breaks reported in Tables 4 and 5. The result equally revealed that only LnAGA and LnEGN are stationary at level while all other variables are stationary at first difference.

TABLE 5 Stationarity test results.

	ADF		PP		KT (2014)	
Coefficients	At level	1ST difference	At level	1ST difference	At level	1ST difference
LnECF	0.7402	0.0003[a]	0.7396	0.0000[a]	3.2370	−18.6679[a]
	(0.2053)	(0.0000)	(0.2136)	(0.0000)	(0.9994)	(0.0000)
LnECG	0.3882	0.0037[b]	0.3759	0.0016[b]	1.1338	−28.7565[a]
	(0.9534)	(0.0220)	(0.9968)	(0.0227)	(0.8716)	(0.0000)
LnTNR	0.7139	0.0003[a]	0.6817	0.0003[a]	−1.0971	−26.3147[a]
	(0.6510)	(0.0003)	(0.6066)	(0.0001)	(0.1363)	(0.0000)
LnGDPC	0.3375	0.1438[b]	0.1788	0.1347[b]	1.5407	−13.6634[a]
	(0.7033)	(0.0134)	(0.6111)	(0.0156)	(0.9383)	(0.0000)
LnCE	0.8092	0.0048[a]	0.6983	0.0048[b]	−0.0512	−19.9121[a]
	(0.9856)	(0.0082)	(0.9861)	(0.0100)	(0.4796)	(0.0000)
LnAGA	0.9982	0.0001[a]	0.9993	0.0001[a]	−2.7771[b]	−26.1503[a]
	(0.1574)	(0.0016)	(0.1802)	(0.0000)	(0.0027)	(0.0000)
LnEGN	0.3496	0.0050[a]	0.3502	0.0050[a]	−1.7147[b]	−31.8452[a]
	(0.1526)	(0.0000)	(0.1463)	(0.0000)	(0.0432)	(0.0000)

Note: [a, b, c] denote, *p*-values, statistical significance level at 1%, 5%, and 10% levels, respectively. ADF = Augmented Dickey-Fuller, PP = Philips Perron while KT = Karavias and Tzavalis (2014) panel unit root test with structural breaks.

TABLE 6 Kao test to cointegration.

	t-Statistics	Prob.
ADF	−4.6910[a]	(0.0012)
Residual variance	0.0257	
HAC variance	0.0169	

Note: [a, b, c] denotes statistical rejection level at 0.01, 0.05, and 0.10 level, respectively.

In addition, the cointegration technique is also shown in Table 6. The Kao cointegration technique offers empirical evidence supporting the presence of a long-term cointegration relationship between the ecological footprint and the explanatory variables. Consequently, the utilization of suitable model estimation techniques, such as Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and Panel Mean Group-Autoregressive Distributed Lag (ARDL), was pursued.

4.3 | Discussion of results

Table 7 shows FMOLS and DOLS results. These statistical methods addressed endogeneity and serial correlation issues in residual values. These two estimating models also examined the factors' long-term effects on EFC. The FMOLS and DOLS data show that economic globalization positively impacts E7 economies' ECF. According to the FMOLS and DOLS models, a 1% rise in economic globalization reduces ECF by 0.265% and 1.4059%, respectively, both significant at the 1% level. The positive correlation between economic globalization and ecological footprint is possible. Economic globalization increases trade and production, which intensifies land, water, and mineral

TABLE 7 Long-run analysis.

Variables	FMOLS	DOLS
LnECG	0.2605[a]	1.4059[a]
Prob.	(0.0011)	(0.0028)
LnTNR	−0.0536	0.0681[b]
Prob.	(0.1454)	(0.0391)
LnGDPC	0.3653[a]	0.3053[c]
Prob.	(0.0009)	(0.0663)
LnCE	−1.2247[a]	−0.4795[c]
Prob.	(0.0001)	(0.0550)
LnAGA	−0.6405[a]	0.3092
Prob.	(0.0015)	(0.3907)
LnEGN	−0.8505[a]	−0.8775[a]
Prob.	(0.0001)	(0.0000)
R^2	0.9756	0.9985
ADJ R^2	0.9738	0.9893

Note: [a, b, c] denote statistical rejection level at 0.01, 0.05, and 0.10 level, respectively.

exploitation and carbon emissions. Thus, economic globalization diminishes biocapacity in emerging economies and increases ecological impact.

Further, the FMOLS calculations indicate that natural resource rent has an inconsequential and adverse impact on ECF, whereas the DOLS analysis reveals a substantial and positive influence of natural resource rent on ECF. In practical terms, a percentage increase in natural resource rent raises ECF by 0.0681% at a significance level of 5% for the DOLS estimator. GDP per capita demonstrates a favorable effect on ECF, with a 1% increase in GDP per capita resulting in ECF increments of 0.365% and 0.305% for FMOLS and DOLS, respectively. Relative to renewable energy, the estimations show that green energy consumption exerts a negative effect on ECF. Specifically, the FMOLS and DOLS estimations suggest that a unit percent rise in green energy consumption reduces the ECF by 1.2247% and 0.4795%, respectively. The FMOLS found agricultural value-added also exerted a negative effect on the ECF. As such, a percentage rise in agricultural value-added decreases the ECF by 0.6405%. Lastly, on this, both estimations models found the oil, gas, and coal sources had an adverse and significant impact on the ECF. In that, a percentage increase in oil, gas, and coal production sources decreases the ECF by 0.8505% and 0.8775% at a 1% level of significance.

The next stage of the analysis assessed the short- as well as long-run dynamics of the connection between the ECF and the independent coefficients. In this regard, results from PMG-ARDL analysis are presented in Table 8. From the results, the independent variables show convergence toward the long-run by −0.4187 magnitude, significant at 5%. According to the estimation model, economic globalization had no statistically significant impact in the short-term. Although, the outcome is positively significant at 1% in the long-run, which is consistent with the results from the FMOLS and DOLS analysis. This means a percentage rise in economic globalization will increase the ECF by 0.6119% in the long-run. This suggests that economic globalization has a significant role in the environmental depletion observed in E7 economies. Natural resources rent exerts a long-run positive effect on ECF, following the result of the result reported in the DOLS estimation technique. Precisely, a percentage rise in natural resources rent will rise the ECF by 0.1044% in the long-run. This suggests that the ecology in the E7 member states is being harmed by the revenue generated from the mining and processing of raw resources. This conclusion is consistent with earlier claims that natural resource revenues are mostly invested in ways to increase production. Gains in productivity from

TABLE 8 PMG-ARDL analysis.

Variable	Coefficient	SE	*t*-Statistic	*p*-value
LnECG	0.6119[a]	0.4140	1.4778	.0001
LnTRN	0.1044[c]	0.0637	1.6372	.0781
LnGDPC	0.5560[b]	0.2529	6.1523	.0153
LnCE	0.4376	0.2997	4.7966	.5617
LnAGA	0.8621[b]	0.2340	3.6832	.0281
LnEGN	−2.3349[a]	1.4860	−1.5711	.0009
Short-run dynamics				
COINTEQ01	−0.4187[b]	0.1863	−2.2474	.0274
D(LnECG)	−0.1649	1.9659	−0.0838	.7334
D(LnECG(−1)	1.7849	1.9520	0.9143	.8646
D(LnTRN)	0.0115	0.0641	0.1798	.5853
D(LnTRN(−1)	0.1165	0.0751	1.5504	.3158
D(LnGDPC)	0.3336	0.6966	0.4790	.2118
D(LnGDPC(−1)	−0.3425	0.5214	−0.6569	.1665
D(LnCE)	0.3360	0.4052	3.2966	.8762
D(LnCE(−1)	−0.0887	0.6038	−0.1469	.9489
D(LnAGA)	0.4470[a]	0.5862	0.7625	.0024
D(LnAGA(−1)	0.1862	0.3308	0.5627	.9289
D(LnEGN)	0.4261	2.2198	0.1919	.2481
D(LnEGN (−1))	−0.5861	3.2812	−0.1786	.6800
C	24.4303	10.8859	2.2442	.0563

Note: [a, b, c] denotes statistical rejection level at 0.01, 0.05, and 0.10 level, respectively.

these types of funding sources will inevitably result in additional environmental deterioration. This is consistent with findings on transition economies by Adedoyin et al. (2020). The long-term estimation of GDP per capita exhibited a statistically significant positive trend at a significance level of 5%. In essence, a percentage increase in natural resource rents charged will raise the degree of ECF by 0.5560%. This suggests that the growth of economic operations in E7 nations will result in increased energy usage and a decline in environmental conditions. The results obtained support findings from Uddin et al. (2017) and Zafar et al. (2019) from the 27 highest pollutant-emitting countries and the United States. The estimation model also reveals that renewable energy consumption exerts a positive impact on ECF both in the short- and long-runs (0.3360 and 0.4376), although not statistically significant in both runs. This goes against what we assumed a priori. This denotes the nature of sustainable energy usage to encourage the degradation of the environmental quality is not valid, although there is the possibility of such consequential effect of renewable energy use.

Regarding the impact of agricultural value-added, the PMG estimator reveals substantial and positive effects in both the long- and short-term, with coefficients of 0.8621 and 0.4470, respectively. These results differ from what was found using the FMOLS estimator. Nevertheless, the DOLS estimator exhibited a similar effect but lacked statistical significance. This implies that environmental challenges are intricately linked with agricultural production and its influence on environmental issues such as climate change, soil degradation, and waste. An increase in agricultural production entails the cultivation of large expanses of cropland and the destruction of the ecosystem, which raises the ecological footprint of the nations and deteriorates the ecosystem. This outcome falls in line with the submission of Adedoyin et al. (2020) for the same E7 economies. It also conforms to the findings of Çetin et al. (2020) and

Waheed et al. (2018) who highlighted the nexus between agricultural production and environmental degradation. More so, the PMG estimator reveals that oil, gas, and coal sources negatively influence ECF only in the long-run. This assertion is also in line with the findings from the FMOLS and DOLS estimators. This result is in direct contrast to this study's hypothesis. Meanwhile, the findings support the postulation of Sarwar et al. (2019).

5 | CONCLUSION AND POLICY RECOMMENDATIONS

This study investigates the relationship between real GDP, natural resource rent, financial globalization, and agricultural value-added in the E7 economies of Brazil, Russia, India, Indonesia, Mexico, Turkey, and China. It contributes to existing knowledge by investigating ecological factors like renewable energy, financial globalization, GDP, and natural resource rent. The research uses various estimating methods, such as DOLS, FMOLS, and PMG-ARDL, to ensure high accuracy and robustness in estimations.

The findings indicate a positive and statistically significant association between economic globalization and ecological footprint, suggesting that as economic globalization grows, so does the ecological footprint in E7 nations, hence results in degradation of environment. The growing economic interdependence among nations fosters industrialization by boosting output and expanding energy consumption, consequently affecting environmental quality. This is contrary to the submission of Çetin et al. (2023) that increase in globalization improves environmental sustainability. Furthermore, the findings regarding natural resource revenue indicate an affirmative impact on the ecological footprint, suggesting that greater natural resource income contributes to environmental deterioration by increasing the ecological footprint. Government regulation of natural resources and the reinvestment of revenue in production improvement in the E7 nations' result in increased productivity that poses serious environmental threats. Furthermore, the results of the real GDP estimation align with expectations, indicating a positive and statistically significant relationship between real GDP and the ecological footprint. This implies that unchecked constructive activities in the region will exert further pressure on the environment, leading to depletion.

Similarly, the findings show a notable positive influence of agricultural value-added on the ecological footprint, indicating that agricultural efficiency plays a pivotal role in environmental deterioration. This association is closely tied to soil degradation, deforestation, and water scarcity resulting from crop cultivation and livestock farming. In addition, the research reveals an adverse effect of utilizing oil, coal, and gas on the ecological footprint, underscoring that generating energy from these sources is a viable choice for maintaining environmental sustainability.

Based on the findings, this research offers suggestions for enhancing and preserving environmental quality and sustainable development not only in E7 economies but also globally. It is evident that unfettered economic globalization could pose risks to the environment due to unregulated growth among nations. Instead of this approach, policymakers should contemplate the development of national policies that prioritize the assessment of environmental impacts before entering into trade agreements or establishing economic interdependence with other countries. This signifies that environmental protection agreements should take precedence over trade deals. The policy implication of this approach is that it places a higher priority on safeguarding environmental quality to shield ecological well-being from the adverse consequences of economic globalization.

Moreover, policymakers should focus their efforts on incorporating environmental damage costs alongside natural resource rents. This measure is intended to instil environmental consciousness among natural resource extractors regarding their economic activities. Such regulatory measures are essential to safeguarding the environment against degradation by discouraging unchecked resource extraction and ultimately enhancing environmental sustainability. Consequently, policymakers must implement stringent regulations aimed at shifting from environmental degradation toward a cleaner environment. Finally, it is imperative to reform agrarian methods to minimize their detrimental impact on the ecosystem. Excessive emissions resulting from enteric fermentation in feeding practices have caused substantial environmental threats, which are not prerequisites for improving crop production. There is a need for initiatives aimed at enhancing agricultural practices to align them with environmental sustainability goals.

Although the present study explores the nexus between ecological footprint on key macroeconomic variables for the E7 countries, future study can explore the theme with the use of load factor and consider variables such as economic complexity for other blocs such as MENA, SSA among others to either affirm or refute the current study findings.

The limitation of this study is that it considered only the E7 countries and did not compare it with other economic blocs. Also, political and social globalization are not captured in the study. Therefore, further studies which fill in this gap would provide insightful policy directions.

DATA AVAILABILITY STATEMENT

WDI- Word Bank development indicator-2022 database while GFN-Global footprint network-2022 database.

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APPENDIX A

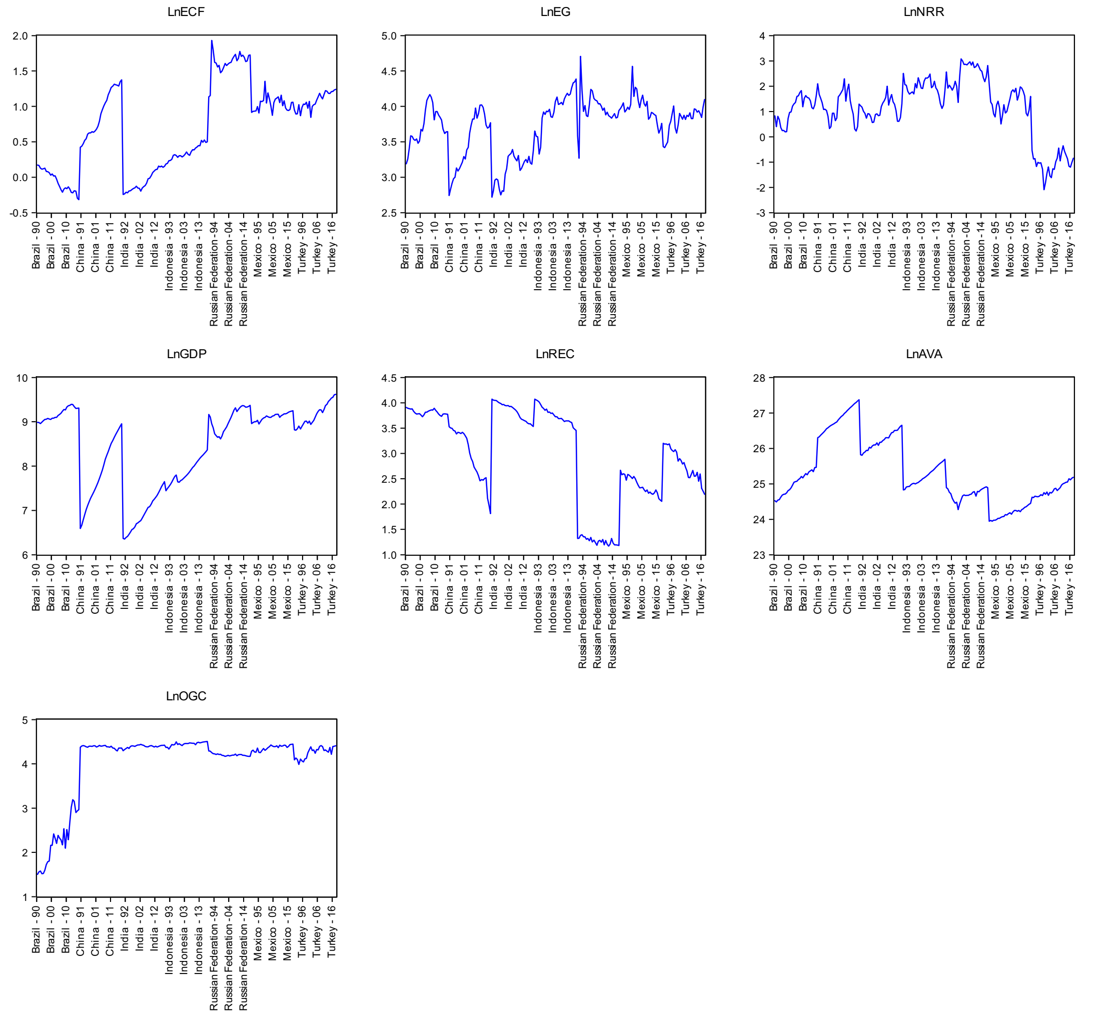

FIGURE A1 Trend of variables.