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Gravitating towards emission reduction targets in the G7 and E7 economies: the financial development and sustainable energy perspectives

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ABSTRACT

Governments throughout the globe are confronted with climate change issues. In the wake of the climate change conference COP26—the Glasgow consensus, the criticality of attaining emission reduction targets to restrain global average temperature to 1.5 degrees has been reemphasized. Hence, we assessed these laudable climate action targets from the financial development and sustainable energy perspectives within the E7 and G7 economies. In lieu of this, the application of Augmented Mean Group (AMG) and Quantile regression techniques on annual frequency data from both blocs between 1990 and 2019 provide useful insights into the cruciality of financial development and renewable energy in CO_2 mitigation toward attaining the 1.5°C vis-à-vis the net-zero emission goals. The empirical outcome shows that renewables create paths to emissions reduction targets in both blocs. Furthermore, financial development corroborates renewables' emission reduction roles specifically in the E7. Additionally, renewables' interactive roles with the expanding economic growth trajectory of both blocs also induce emission-mitigating effects. Finally, an inverted U-Shaped EKC phenomenon was validated. Hence, green growth policies corroborated by financial expansion strategies are recommended and deemed apt for attaining net-zero emission targets in these strategic economic blocs.

KEYWORDS
Financial development, sustainable environment; 1.5°C & net-zero emission; renewable energy; E7 & G7 economies

1. Introduction

Achieving economic development while preserving a high-quality environment is a critical objective for global economies and stakeholders alike (Wang & Zhang, 2021). The escalating anthropogenic activities resulting from human socio-economic roles in our evolving societies have significant environmental consequences. Specifically, activities inducing economic growth have been identified as common contributors to the increasing anthropogenic occurrences (Shen et al., 2021; Zaidi et al., 2019). Therefore, a growth-determining factor, such as energy consumption, is a crucial component of economic development that requires careful examination of sustainable environmental efforts (Zhao et al., 2021; Su et al., 2021).

To achieve greater economic progress, countries consistently rely on energy to sustain production across industries and other productive sectors. Thus, energy consumption lies at the core of

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industrialization and economic expansion (Baloch et al., 2021; Ummalla and Goyari 2021). Moreover, there is a growing importance of clean and efficient energy sources in ensuring sustainable economic expansion. However, the use of conventional fossil sources continues to dominate the economic growth activities of many countries. Consequently, there is an increasing combustion of unclean energy sources, leading to a rise in greenhouse gases (GHG), especially carbon emissions (Chien et al., 2021). In response, the calls to intensify the transition from fossil fuel sources to clean energy sources continue to grow.

While clean energy sources are inexhaustible, cleaner, and safer for the environment (Cai et al., 2021), conventional nonrenewable energy sources deteriorate over time and also pollute the environment. It has been consistently suggested that a positive link exists between clean energy expansion and a healthier environment (Chien et al., 2021; Behera & Mishra, 2020; Aslan et al., 2022). For example, Behera and Mishra (2020), and Bilgili and Ozturk (2015) both validate the link among G7 countries. The same assertion is also upheld by the evidence presented by Asiedu et al. (2021); Ntanos et al. (2018); Kasperowicz et al. (2020); Papież et al. (2019), among Asian states (Liu et al., 2018; Lu, 2017), as well as among African and Latin American states (Solarin & Ozturk, 2015; Pablo-Romero and De Jesús, 2016).

The evident interest in understanding the role of clean energy sources within a sustainable economic development framework is driven by their expected contribution to mitigating environmental degradation through reduced carbon dioxide emissions. Furthermore, the challenge of a country's inability to sustain the regeneration of nonrenewable energy sources for the future emphasizes the importance of focusing on clean energy sources. Despite ample evidence establishing the link between economic development and clean energy consumption, few examinations have undertaken a comparative assessment of this nexus among strategic nation blocs, particularly between G7 (USA, UK, France, Japan, Germany, Italy, and Canada) and E7 (Turkey, Indonesia, Mexico, Brazil, Russia, India, and China) countries (Ozcan & Ozturk, 2019; Chang & Fang, 2022).

The rationale behind this comparative assessment is to provide a basis for benchmarking and formulating realistic environmentally friendly objectives to drive the attainment of a global 1.5°C goal toward a net-zero target. E7 and G7 member countries are among the world's fastest developing and developed economies, respectively. Therefore, this study prioritizes researching these blocs due to their observed dominance over the global economic order and their increasing carbon emission rates.

Economic reports indicate that the economic expansion of E7 economies was around \$22.377 trillion compared to \$38.468 trillion for G7 countries in 2019 (World Bank, 2021). The steady growth of E7 countries is accompanied by increased energy utilization, driving CO2 emissions. British Petroleum, (2021) estimates that 46% of global carbon emissions are generated by E7 countries alone. At this rate, E7 countries are projected to reach 50% of the world's GDP by 2050, suggesting a massive shift in economic power from G7 to E7, potentially diverting from the global sustainable development goal.

As these countries accelerate in economic power, the potential consumption of energy leading to more pollutant emissions may aggravate (Itkonen,2012; Banday & Aneja, 2020; Moshin et al., 2021; Bozkaya et al. 2022). Experts perceive that a massive expansion of clean energy generation is crucial to achieving the 1.5°C and net-zero global target; however, the road to this objective is daunting with many obstacles. For instance, transitioning to renewable or clean energy sources requires significant financial obligations. However, the high cost of capital required for these projects remains a stumbling block for many countries. Despite the desire to invest in clean energy sources and shy away from conventional fossil energy sources, significant constraints in the supply and demand of finances pose challenges. This inevitably underscores the importance of financially developed systems and sectors to increase clean energy production and consumption.

Previous studies have unraveled a complex interconnection between financial development and environmental sustainability consequences. For example, Khan and Ozturk (2021) observed that the growth of financial services appears to positively impact energy consumption, influencing the release of CO2 emissions. Additionally, the prevalent pattern linking financial development to increased economic growth and carbon emissions, as observed by Khan and Ozturk, accentuates a complex balancing act. The significance of financial development for economic growth often results in environmental harm due to swift expansion. Furthermore, Aluko and Obalade (2020) concluded that a developed financial sector serves as a bedrock for finances required to advance green energy expansion projects and technology.

Musa et al. (2021) support the notion that developed financial systems are crucial for making funds accessible to firms to invest in technology and energy-efficient modes of production, thus mitigating the impact of pollutant emissions. These assessments directly link financial development to driving environmental sustainability targets like below 1.5°C and net-zero carbon emissions. Hence, Nakhli et al. (2022) and Appiah et al. (2022) have all observed that reduced utilization of traditional nonrenewable energy or greater use of clean energy sources is required to achieve carbon-free economies, and adequate financial development is required to drive this objective (Umar et al., 2021). These observations underscore the significance of steady financial development within economic systems to affect environmental sustainability.

However, despite the existence of these observations, nuanced conclusions on the role of financial development in environmental sustainability persist. Studies suggest inconsistent observations on the positive role of financial development for environmental sustainability, indicating a lack of consensus on the issue. For example, Wang et al. (2020) conceive that financial development will drive consumer credits, increasing household consumption of items such as automobiles and other household consumables that tend to increase household generation of carbon dioxide emissions. A similar case is made for emerging firms, unable to acquire more expensive technology and equipment to drive energy-efficient modes of production but rather to expand production and rely on fossil fuel energies (Lahiani et al., 2021).

This inconsistent spectacle of the role of financial development for environmental sustainability poses new challenges in both developed and emerging economies. For instance, for the third consecutive year, the world confronts significant destabilizing crises, further intensified by the climate emergency, engendering vulnerabilities in global economies, affecting both G7 nations and developing/emerging economies. The growth rate of the gross domestic product (GDP) in the G7 nations is predicted to decelerate, potentially reaching a slightly negative value (Statista, 2023). These projections suggest the need for greater stabilization in the following years for these countries. Experts suggest it is imperative to enhance the resilience and greater development of the financial system to address these risks facing developed and emerging economies. Thus, there is a need for greater expansion and proactivity to safeguard financial and economic stability in the face of ongoing crises. Linking this to the nuanced effects of financial development observed in prior studies presents greater confusion about the crucial role of financial development in environmental sustainability. Therefore, there is a need for new evidence from new contexts to further expand our understanding of the role of financial development in mitigating negative impacts on clean energy expansion goals for the long term.

This study contributes significantly to the existing literature on clean energy expansion, financial development, and pollutant emissions in several ways. Firstly, it conducts a comparative assessment of the effects of financial development and clean energy expansion on carbon dioxide emissions in G7 and E7 member states, offering recommendations for mitigating remedies. Notably, the study observes the steady growth of financial development in the E7 domestic banking sector, poised to reach half of that in the G7. Moreover, predictions indicate that economic development in E7 countries will surpass the current G7 by approximately 25% in terms of GDP (PWC, 2019). Projections based on market exchange rates suggest that China's total domestic credit is expected to overtake G7 states like the UK, Germany, Japan, and the USA by 2050, with India also rising steadily to become one of the largest domestic markets globally by the same year. These observations signify the significant impact of financial development on economic growth and the potential for renewable energy development.

Again, the study addresses gaps in existing research by analyzing the extent to which financial development and clean energy expansion influence carbon dioxide emissions between E7 and G7, aligning with the 1.5°C goals and net-zero emission targets. Thirdly, the study distinguishes itself by accounting for cross-sectional dependence, heterogeneity, and multicollinearity using second-generation robust techniques. This approach provides fresh evidence for both micro and macro-level decision-making, offering insights to drive emission mitigation efforts and achieve carbon neutrality targets.

2. Literature review

2.1. Financial development and CO_2 emissions

Financial development plays a central role in economic progress and modernization. While economic development and modernization are crucial indicators of human development, financial development also poses significant threats to environmental quality. The relationship between financial development and CO_2 emissions has been extensively analyzed, yet consensus on the direction and magnitude of the effects remains elusive. Some studies, such as Shen et al. (2021) and Acheampong (2019), suggest a positive impact of financial development on pollution. For example, Shen et al.'s study on 30 provinces in China concluded that FD heightens emissions. Evidence from 46 African countries also points to the direct and indirect influence of financial development on carbon emissions, facilitating CO_2 increases in the region (Acheampong, 2019).

Contrastingly, studies like Zaidi et al. (2019) examining APEC nations from 1990 to 2016 and Umar et al. (2021) in China propose that FD reduces carbon emissions both in the short and long run. A strand of scholars, including Salahuddin et al. (2018) and Köksal et al. (2021), found no significant effect of FD on CO2 emissions. These divergent findings indicate a lack of consensus on FD's carbon reduction propensities.

Furthermore, there is a paucity of examinations on this relationship within the G7 and E7 blocs. While scholars have studied member countries individually, evaluations considering these countries as a bloc are still in their early stages. Given the growing prominence of these countries, especially the E7 nations, an aggregated assessment would provide new insights into the role of FD in achieving the global 1.5°C target for a net-zero carbon emissions universe.

2.2. Renewable energy, economic expansion, and emissions linkages

Over the past few years, studies focusing on clean energy consumption and economic expansion and their impact on emissions sources like carbon emissions have grown exponentially. The majority of these studies examining this phenomenon have sought an understanding of the economic expansion and clean energy nexus (Wang et al. 2022). The literature proposes four hypotheses, testable for the clean energy expansion nexus: First, the "growth hypothesis, conservative hypothesis, feedback and neutrality hypotheses." The unidirectional causal link running from clean energy to economic expansion indicates that growth in clean energy utilization will increase economic expansion. While the conservative view or hypothesis depicts the one-way association running from economic expansion to clean energy utilization, thus suggesting economic expansion drives energy intake. Also, the presence of a two-way causality link between clean energy utilization and economic expansion shows a validation of the feedback assumption. Finally, the neutrality perspective spells out the nonexistence of a direct association between economic expansion and clean energy use. All these assumptions have been validated with different samples and evidence from different contexts in the literature. For instance, Inglesi-Lotz, (2016) observed a positive link between renewable energy and economic expansion. Indicating clean energy expansion possesses desirable outcomes for environmental quality and human development. A similar attempt by Gozgor et al. (2018) showed a validation of the growth assumption that clean energy utilization positively impacted economic expansion among OECD states. Jebli and Youssef (2015) reported a similar validation of the growth hypothesis. Using a cointegration and causality test to assess the clean energy intake and economic expansion nexus, Bulut and Muratoglu (2018) observed an insignificant connection between clean energy utilization and economic growth in Turkey. Their study showed the proportion of clean energy utilized in Turkey was too small to significantly impact economic expansion. Contrary to the findings of Bulut and Muratoglu, (2018), Ocal and Aslan (2013) earlier found a significant link between clean energy intake and economic expansion in Turkey. By applying the ARDL and Toda-Yamamoto causality techniques, the study's results confirmed the protection hypothesis in Turkey.

In Lin and Moubarak's, (2014) study on China, a two-way linking connection exists among clean energy utilization and economic expansion is established. Thus, economic expansion in China drives the expansion of clean energy utilization, hence validating the feedback assumption of this nexus. Evidence from Germany showed a validated feedback effect from (1971–2013) between economic expansion and clean energy utilization (Rafindadi and Ozturk 2017). Based on the above discussed, a vast attempt of empirical examinations exists on the association between clean energy utilization and economic expansion, of which all four assumptions are proven to exist. However, the effects of these economic development indicators on carbon emissions remain widely unclear (Wang et al. 2022). This is mostly attributed to the fact that most analyses have absorbed the connection between these two and few considered their effect on agents of environmental quality like carbon emissions. Further, a few that have attempted this examination suggest a nonlinear relationship between clean energy utilization, economic growth, and carbon emissions (Tugcu et al. 2012, Tugcu and Topcu 2018, Luqman et al. 2019). Thus, there is a need to bridge this gap. In that, new examinations can show whether clean energy utilization and economic expansion show symmetric emission- increasing influence or otherwise.

2.3. Research gap

In summary, this review presents insights from prior empirical works on the causal linkages existing between economic expansion, clean or renewable energy utilization, and environmental quality determined by carbon dioxide emissions. Our preliminary observations indicate several studies exist on these variables from perspectives that differ from the view of this current study. First, most of these examinations have considered interactions between clean energy utilization and economic expansion, without considering environmental quality. In this current study, we seek to observe the impact of these variables and their joint interaction on environmental quality, which is a departure from the trend observed in the literature. In addition, among most studies considered in this review, the majority have mainly focused on individual economic units like specific countries, whereas few have studied this phenomenon from a broader perspective as sought in this study. This current examination seeks to consider evidence from G7 and E7 blocs, to present a combined insight from global economic giants whose economic actions can affect or improve the global environment considerably. Thirdly, this current examination stands among a few empirical studies to conduct a comparative analysis on the issue of economic expansion activities and clean energy utilization on environmental quality. Most empirical works in the literature have provided single-state evidence which does not provide sufficient information for benchmarking and corrective decision-making.

2.4. Theoretical framework

The strategies taken and the influences of financial development on emissions may differ owing to certain circumstances. Some nations have successfully built financial sectors and institutions as strategic instruments to limit global warming to 1.5°C and attain net-zero emissions. A well-advanced financial sector, according to theory, will cut lending costs and boost investment in green energy and innovations, eventually leading to a reduction in conventional energy use and pollutants (Musa et al. 2021). From a different point of view, a boost in financial inclusiveness and advancement will enhance consumer lending, which will, in turn, boost individuals to spend their money on autos, home goods, and other commodities (Wang et al. 2020). There is no question that this will raise energy requirements as well as environmental impact. To build on the findings of earlier research on carbon neutrality (Lahiani et al. 2021), this approach integrates financial development as a primary determinant in the econometric approach of CO_2 emissions and predicts that it will have a positive influence. Renewable energy usage, on the other hand, has lately emerged as an essential tool for lowering CO_2 emissions. As a result, alternative energy supplies like solar, wind, hydropower, biomass, and geothermal, which release minimal or zero carbon, help to increase energy efficiency and ecological integrity (Adams and Acheampong, 2019) while also improving ambient cleanliness. However, some empirical investigations have highlighted green energy as a critical aspect of controlling the climate crisis and achieving net-zero emissions (Nakhli et al. 2022). According to prior research, this study incorporates renewable energy usage as the primary predictive coefficient in the model and anticipates that it will have an adverse impact on emissions.

Furthermore, per capita income is essential for a nation to stimulate economic growth, raise the quantum of income, and improve the living standards of its population. According to the traditional hypothesis of economic growth, higher income activity results in higher energy consumption and environmental damage. The EKC theory proposed by (Grossman and Krueger, 1991) claims that although income originally affects the environment, it subsequently enhances the health of the climate once a specific income threshold is achieved. This approach may be theoretically used to link growth to emissions. Several investigations have employed the EKC structure estimations in their assessments (Tenaw and Beyene 2021; Wang et al. 2022). Therefore, this analysis incorporates economic growth into the framework and anticipates that economic growth will have a favorable influence on CO_2 emissions, as well as an adverse influence on CO_2 emissions for its squared. The structural model for this investigation is stated in the EKC structure as:

$$\mathrm{LCO2}_{it} = \beta_0 + \beta_1 LFD_{it} + \beta_2 LY_{it} + \beta_3 LY2_{it} + \beta_4 LREC_{it} + \varepsilon_{it} \tag{1}$$

where CO_2 denotes carbon dioxide releases, FD as financial development, Y as economic growth, and its square as Y^2 while REC denotes renewable energy usage. This relationship is expressed in the model presented as follows:

$$\mathrm{LCO2}_{it} = \beta_0 + \beta_1 LFD_{it} + \beta_2 LY_{it} + \beta_3 LY2_{it} + \beta_4 LREC_{it} + \beta_5 LY * LREC_{it} + \varepsilon_{it} \tag{2}$$

where Y*REC denotes the interaction between economic growth and clean energy. As noted, some studies have argued that a developed financial sector serves as a bedrock for finances required to advance green energy expansion projects and technology (Aluko and Obalade, 2020). Also, it has been argued that developed financial systems are crucial for making funds accessible to firms to invest in technology and energy-efficient modes of production, thus mitigating the impact of pollutant emissions (Musa et al. 2021, Umar et al. 2020, 2021).

These assessments directly link financial development as part of the driving forces for environmental sustainability targets like keeping the temperature below 1.5°C and net-zero carbon emissions, thus, underscoring the significance of steady financial development within economic systems to affect environmental sustainability. In this regard, private firms and their initiatives have been at the forefront of the sustainability drive including most R&D investments in green innovations among others.

Meanwhile, contrary arguments have also been put out that developed financial systems will drive consumer credits, increasing household consumption of items such as automobiles and other household consumables that tend to increase household generation of carbon dioxide emissions (Wang et al. 2020). It has been argued for instance that, upcoming private firms may be unable to acquire more expensive technology and equipment to drive energy-efficient modes of production which may leave them with no alternative than to heavily depend on fossil fuel energies (Lahiani et al., 2021).

Whichever is the case, the availability of funds to the private sector remains an important indicator of the financial development level. This indicator has also been noted to be of more benefit when financial development is to be viewed from the banking perspective (Onifade et al. 2023a). The indicator relates to total financial growth based on how accessible funds are to the private sector. While we agree to the possibility of alternative indicators for financial development to include but are not limited to proxies like National Stock price volatility which encompasses the average of the 360-day volatility of a nation's stock market index. Although the G7 has better data availability, unfortunately, we are limited in the utilization of such proxies due to the irregularity of relevant data especially for the countries in the E7 case. Overall, if the positive argument for the FD stands, it is important to push for a more resilient and developed financial system to address financial risks facing not only emerging economies but also developed economies like the G7.

3. Data and empirical methods

3.1. Empirical research data

To achieve the set goals of this study, it employs a set of panel data for two blocs of economies namely (the E7[1] and the G7[2]), during the period between 1990 and 2019 due to limitations on the availability of data. Again, the societal and economic changes caused by the pandemic might affect the interpretation of data collected before 2020. For instance, trends identified in pre-pandemic data may no longer hold, or new patterns may emerge in the post-pandemic world. Data on clean energy and CO_2 emissions were acquired from the British Petroleum database (British Petroleum, 2021). Whereas the remaining variables were drawn from the WDI (2021) database. Choosing variables for this study is done in harmony with the 2030 Sustainable Development Goals (SDGs). Table 1 presents a breakdown of the factors used for this study's estimations while their statistical characteristics are provided in Appendix Table A1.

3.2. Methodology

3.2.1. Pre-estimation tests

3.2.1.1. Cross-sectional dependence (CD) & tests of slope homogeneity (SH). Given the increased cross-border trade and increasing trade liberalization, CD in panel regression is expected to be present in the periods considered for this study.[3] Thus, looking out for the presence of CD and eliminating its associated problems will improve the robustness and accuracy of estimates. Hence, the Pesaran (2015)

Table 1. Description of Variables.

Indicators	Their Short forms	Measurement scales	Data Source
CO_2 emissions Per Capita	CO_2	Calculated in their metric tons	British Petroleum, 2021
Financial development	FD	domestic credit to private sectors, % of GDP	WDI, 2021
Economic growth	Y	Proxied by the gross domestic product per capita (2015 Constant USD)	WDI, 2021
Square of Economic growth	Y^2	Proxied by the square of gross domestic product per capita (2015 Constant USD)	WDI, 2021
Renewable Energy	REC	Renewable energy consumption (% of total final energy consumption)	British Petroleum, 2021
Interaction term	Y*REC	Economic growth* Renewable Energy	

Note: all factors are log transformed to control for homoscedasticity of the variables.
Source: Authors compilation.

[1]China, India, Brazil, Turkey, Russia, Mexico, and Indonesia.
[2]U.S., U.K., France, Germany, Italy, Canada, and Japan.
[3]The present study also accounts for perfect collinearity issues and conducted basic correlation analysis and variance inflation factor to circumvent for issues raised in the study of Jaforullah & King (2017).

CD, Pesaran et al. (2008) scale LM, and the Breusch and Pagan (1980) LM techniques are utilized to evaluate the existence of CD in this panel analysis. The technique measurements for the three techniques are shown as:

$$LM = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij}\hat{p}_{ij}^2 \rightarrow \chi^2 \frac{N(N-1)}{2} \quad (3)$$

$$LM_s = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \left(T_{ij}\hat{p}_{ij}^2 - 1\right) \rightarrow N(0,1) \quad (4)$$

$$CD_p = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij}\hat{p}_{ij} \rightarrow N(0,1) \quad (5)$$

$$LM_{BC} = \sqrt{\frac{1}{N(N-1)}} \sum_{N-1}^{i=1} \sum_{N}^{j=i+1} \left(T_{ij}\hat{p}_{ij}^2 - 1\right) - \frac{N}{2(T-1)} \rightarrow N(0,1) \quad (6)$$

Likewise, erroneously estimating a SH whereas heterogeneity subsists might result in misleading results. Consequently, we evaluate the heterogeneity scope by using the Pesaran & Yamagata (2008) method from the Swamy (1970) SH method.

$$\tilde{\Delta}_{SH} = (N)^{\frac{1}{2}}(2k)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - k\right) \quad (7)$$

$$\tilde{\Delta}_{ASH} = (N)^{\frac{1}{2}}\left(\frac{2k(T-k-1}{T+1}\right)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - 2k\right) \quad (8)$$

$\tilde{\Delta}_{SH}$ and $\tilde{\Delta}_{ASH}$ represent the delta tilde and the adjusted delta tilde respectively.

3.2.1.2. Root unit tests. This study next assesses the stationarity properties of the factors by utilizing the 2nd generation panel stationarity technique which is robust to CD and SH techniques. We employ Pesaran's (2007) CD-augmented IPS tests. This is also known as the CIPS technique. The CADF technique is shown as:

$$CADF_i = t_i(N,T) = \frac{\left(y_{i,-1}^T \bar{M} y_{i,-1}\right)^{-1}\left(y_{i,-1}^T \bar{M}\Delta y_i\right)}{\sqrt{\sigma_i^2}\left(y_{i,-1}^T \bar{M} y_{i,-1}\right)^{-1}} \quad (9)$$

The assessment of CIPS is created by adopting the means in CADF technique measurements as fellow;

$$\widehat{CIPS} = \frac{1}{N}\sum_{i=1}^{n} CADF_i \quad (10)$$

Now, the cross-sectional ADF outcomes of Eq-9 are symbolized by the Eq-10's CADF notation.

3.2.1.3. The cointegration checks. We evaluated the long-run inter-connectedness of the factors based on the Westerlund (2007) cointegration method in this analysis. Different from the 1st generation cointegration technique, this method reflects on CD as well as the SH. The assessment is shown as follows:

$$\alpha i(L)\Delta y_{it} = y2_{it} + \beta_i(y_{it} - 1 - {}_i x_{it}) + \lambda_i(L)v_{it} + \eta_i[11] \quad (11)$$

whereas $\delta_{1i} = \beta_i(1)\hat{\vartheta}_{21} - \beta_i\lambda_{1i} + \beta_i\hat{\vartheta}2_i$ and $y2_i = -\beta_i\lambda 2_i$
The subsequent are the examination measurements for the Westerlund cointegration:

$$G_t = \frac{1}{N}\sum_{i-1}^{N}\frac{\acute{\alpha}_i}{SE\left(\acute{\alpha}_i\right)} \tag{12}$$

$$G_\alpha = \frac{1}{N}\sum_{i-1}^{N}\frac{\mathrm{T}\acute{\alpha}_i}{\acute{\alpha}_i(1)} \tag{13}$$

$$P_T = \frac{\acute{\alpha}}{SE\left(\acute{\alpha}\right)} \tag{14}$$

$$P_\alpha = \mathrm{T}\,\acute{\alpha} \tag{15}$$

The group means statistics, containing G_a and G_t, are presented in equation-12 and 13. Panel statistics, comprising P_a and P_t, are denoted by equation-14 and 15.

3.2.2. Quantile regression (QR) and augmented mean group (AMG)

The current study attempts an application of analysis procedure robust for the long-run econometric analysis, specifically the Augmented Mean Group and the Quantile Regression analysis procedures. The Quantile regression technique pioneered in the works of Koenker and Bassett (1978), Koenker (2004), and Powell (2016) correspondingly, allows for the observation of the conditional distribution impacts of the regressors on the ecological footprint of the nations sampled. The outcomes obtained in this analysis are adequate for effective suggestions.

$$QLCO2_{it}(\tau/X_{it}) = \beta_i^{(\tau)} + \beta_1^{(\tau)}LFD_{it} + \beta_2^{(\tau)}LY_{it} + \beta_3^{(\tau)}LY_{it}^2 + \beta_4^{(\tau)}LREC_{it} + \beta_5^{(\tau)}LY * LREC_{it} + \varepsilon_{it} \tag{16}$$

Equation 16 represents the conditional quantile of carbon emissions$QLCOE_{it}(\tau/X_{it})$. In this model, τth represents the connections between factors in the baseline Equation 4, supposing X_{it} denotes the vector of independent factors. However, tau (τ) denotes the selected quantiles for the data panels or selected countries i in time t whereas the variables of the slope for the different factors as well as the error term for the vector are demonstrated with φit and β correspondingly. Uniting these techniques contributes to reducing erroneous outcomes and biases in the model (Onifade et al. 2023c).

Relative to the AMG technique, the heterogeneous panel estimator of Eberhardt and Bond (2009) and Eberhardt and Teal (2010) were employed in this analysis as expressed in equation 17:

$$\Delta Y_{it} = \alpha_i + \beta_i\Delta X_{it} + \sum_{t=1}^{T}\pi_t D_t + \varphi_i UCF_t + \mu_{it} \tag{17}$$

The Ordinary Least Squares model of alteration is applied to the Augmented Mean Group test. This is expressed in equation 18, in which φ_i symbolizes the estimated slope parameters of X_{it} factors expressed in equation 17.

$$\mathrm{AMG} = \frac{1}{N}\sum_{i=1}^{N}\varphi_i \tag{18}$$

Table 2. The CD & SH Analyses.

	Pesaran CD	Pesaran scaled LM	Breusch-Pagan LM	Pesaran CD	Pesaran scaled LM	Breusch-Pagan LM	Pesaran CD	Pesaran scaled LM	Breusch-Pagan LM
Variables	E7 ECONOMIES			G7 ECONOMIES			COMBINED ECONOMIES		
LCO_2	18.864*	51.247*	360.119*	11.779*	36.231*	262.805*	14.111*	81.186*	1200.271*
LFD	5.799*	13.239*	113.804*	13.889*	54.080*	378.480*	4.516*	60.255*	917.885*
LY	19.534*	54.955*	384.154*	21.558*	69.593*	479.016*	38.337*	111.745*	1612.532*
LREC	11.935*	31.892*	234.685*	4.5405*	41.449*	296.624*	17.106*	65.644*	990.598*
LY*LREC	4.796*	20.772*	162.620*	4.094*	35.189*	256.054*	7.690*	51.930*	805.576*
	COEFFICIENT			COEFFICIENT			COEFFICIENT		
Slope Homogeneity (SH)									
SH ($\tilde{\Delta}$ test)	5.055*			3.456*			6.012*		
SH ($\tilde{\Delta}$ adj test)	6.009*			4.435*			7.103*		

Note: *<0.01.

Table 3. The panel unit root Analysis.

	I(1)		I(1)		I(1)	
	E7		G7		Panel of E7 and G7	
Variables	C	C&T	C	C&T	C	C&T
LCO_2	−3.183*	−3.682*	−5.743*	−5.763*	−4.283*	−4.170*
LFD	−3.847*	−3.109*	−2.628*	−3.883*	−3.864*	−3.850*
LY	−3.806*	−3.171*	−3.844*	−3.949*	−2.582*	−3.308*
LREC	−2.976*	−3.874*	−5.024*	−5.042*	−4.224*	−4.238*
LY*LREC	−2.663*	−4.283*	−4.732*	−4.800*	−3.784*	−4.382*

Note: *<0.01 level of significance. Meanwhile, the (C) is for constant model &; (C&T) is for constant and trend models.

4. Empirical results and their discussion

4.1. Pre-estimation test results

The outcomes in Table 2 show the findings from the CD assessments which reject the null hypothesis of no CD at a one percent significance level for E7 and G7 economies. The rejection of the null hypothesis for the SH checks was also affirmed at a one percent level of significance which in turn suggested to us that all the other empirical investigations need to reflect the capacity to be able to produce dependable outcomes given the affirmed CD & SH problems that marred the data size. Due to these developments, the CIPS analysis for the unit root test can be seen in Table 3 and valid long-run connection in the series was reported in Table 4.

Observed in Table 5, the analysis results of the QR and AMG techniques indicate quite close outcomes, with minor variations particularly relative to the scales of the assessed factors and their respective levels of significance. Though, both methods reveal, from the combined assessments of both categories of the economies that, financial development, clean or renewable energy as well as the interaction between economic growth and renewable energy all exert a negatively significant influence on the understudy economics while an inverted U-shaped EKC is obtained from

Table 4. The cointegration Analysis.

Tests Statistics	E7		G7		Panel of E7 and G7	
	Value	p-value	Value	p-value	Value	p-value
Gτ	−3.776*	(0.009)	−2.041*	(0.006)	−4.416*	(0.008)
Gα	−4.268*	(0.002)	−7.215*	(0.009)	−3.102*	(0.000)
Pτ	−2.878*	(0.005)	−4.933*	(0.002)	−5.237*	(0.000)
Pα	−2.389*	(0.001)	−6.188*	(0.009)	−4.378*	(0.006)

Note: *<0.01.

economic growth and its square's impact on environment sowing that, it is both negative and positive significant signs obtained from the analysis. However, the novelty of this investigation is the comparison of the two strong economies. From Table 5, it is observed that a unit rise in FD will improve environmental quality by 0.886% at Qtil-0.25, 0.668% at Qtil-0.50, 0.591% at Qtil-0.75, and 0.589% at AMG for E7 economies. On the other hand, for G7 economies, a percentage change in financial development will reduce environmental quality by 0.257% at Qtil-0.25, 0.212% at Qtil-0.50, 0.777% at Qtil-0.75, and 0.329% at AMG. This indicates that financial development contributes to greater emissions than it decreases. Moreover, our analysis shows that access to finance and advancement may increase CO_2 emissions in E7, but that they are a vital metric in reducing CO_2 emissions in G7 to a considerable level. This lends credence to the findings of (Khan and Ozturk 2021; Bashir et al. 2022,; Qin et al. 2022; Qin et al. 2023; Su et al. 2023) which found that well-established finance systems are required in industrialized nations to attain net-zero emission goals. In addition, these outcomes from E7 are similar to the analytical outcomes of Al-Mulali and Sab, (2012), Khezri et al. (2021), and Xu et al. (2021), who all show that financial development boosts CO_2 emissions in emerging economies. Although several attempts have been made, financial development continues to be a significant concern in the Asian and African areas, particularly in emerging nations (Cicchiello et al. 2021) which have much of the E7 economies. A comparable conflict exists in many growing economies involving the necessity to invest in clean energies and the need to minimize the number of automobiles as well as gadgets that require conventional energy, which results in greater pollutants. This shows that the rise of the financial industry and cheap capital investment in emerging economies have encouraged CO_2 emissions above the promotion of responsible growth. Currently, some nations have successfully anchored their financial industries as a means of achieving their net-zero carbon objectives while maintaining economic growth. This boosts credit facilities and motivates individuals to spend their financial resources on automobiles, consumables, and other commodities, all of which are associated with excessive energy usage and carbon emissions. To achieve a low-carbon society, it is necessary to make major adjustments in the way financial institutions, as well as the public and private industries function.

Furthermore, for renewable energy intake, a negative significant impact on emissions is established for all the economies under study. From the outcome, it can be seen that G7 economies have a greater coefficient than E7, thus, a percentage downturn in renewable utilization will reduce the environment's quality level by 0.512% at Qtil-0.25, 0.156% at Qtil-0.50, 0.716% at Qtil-0.75, and 0.252% at AMG for the E7 economies while a percentage change in renewable energy will reduce environmental quality by 1.251% at Qtil-0.25, 1.192% at Qtil-0.50, 1.417% at Qtil-0.75, and 1.634% at AMG for the G7 economies. This suggests that the use of clean energy is associated with the reduction of CO_2 emissions, which has been confirmed by several subsequent analyses (Anwar et al. 2021, Adebayo et al. 2022, Yu et al. 2022). With the help of environmental-related technology innovations, several nations have educated their populations off fossil fuels, established alternative energy supplies, and switched their manufacturing to more green technologies, such as renewables. According to this study's results, expanding renewable energy utilization enhances environmental conditions considerably in the long run. To move the world toward a net-zero energy future, it's also important to have green energy sources.

Additionally, it has been demonstrated that economic growth as well as the square of economic growth have both favorable and adverse effects on carbon emissions, validating the presence of the EKC assertion for E7 and G7 economies. This demonstrates that nations must reach a particular economic cutoff point to reduce CO_2 emissions and attain the 1.5°C and net-zero emissions objectives. Following the EKC theory, these results are consistent with novel observations (Obobisa , Khan and Ozturk 2021), which demonstrated an inverted U-shaped under the EKC theory in a similar manner. In contrast to the conclusions of Erdoğan et al. (2020), and Adu & Denkyirah (2017), who determined that the EKC is flawed, our results are inconsistent with their observations. Concerning the interaction between economic growth and renewable energy on CO_2 emissions, it is observed that from all the

Table 5. QR and AMG Empirical Analysis.

Variables	AMG	Qtil-0.25	Qtil-0.50	Qtil-0.75
E7				
LFD	0.589***	0.886*	0.668*	0.591*
p-value	(0.089)	(0.00)	(0.005)	(0.005)
LY	0.903*	0.313**	0.208***	0.734**
P-value	(0.00)	(0.011)	(0.071)	(0.010)
LY^2	−0.061*	−0.501**	−0.029**	−0.452***
p-value	(0.00)	(0.047)	(0.020)	(0.085)
LREC	−0.252*	−0.512*	−0.156***	−0.716**
p-value	(0.000)	(0.00)	(0.080)	(0.010)
LY*LREC	−0.286*	−0.642*	−0.197***	−0.470**
p-value	(0.000)	(0.000)	(0.084)	(0.033)
Wald test	912.20*	-	-	-
P -value	(0.000)	-	-	-
Pseudo R^2/R^2	-	0.246	0.357	0.363
G7				
LFD	−0.329**	−0.257*	−0.212**	−0.777*
p-value	(0.046)	(0.001)	(0.026)	(0.000)
LY	0.980**	0.512**	0.642***	0.588*
p-value	(0.032)	(0.024)	(0.053)	(0.002)
LY2	−0.298***	−0.389*	−0.471*	−0.279*
p-value	(0.071)	(0.000)	(0.000)	(0.009)
LREC	−1.634*	−1.251***	−1.192**	−1.417**
p-value	(0.008)	(0.061)	(0.025)	(0.039)
LY*LREC	−0.691**	−1.503**	−1.792**	−1.541**
p-value	(0.024)	(0.044)	(0.027)	(0.016)
Wald test	45.456*	-	-	-
p-value	(0.002)	-	-	-
Pseudo R^2/R^2	-	0.379	0.305	0.324
E7 and G7 Panel				
LFD	−0.335*	−0.078**	−0.143**	−0.378*
p-value	(0.007)	(0.013)	(0.036)	(0.003)
LY	0.430*	0.254*	0.782*	0.648*
P -value	(0.00)	(0.000)	(0.00)	(0.000)
LY2	−0.155*	−0.516**	−0.464*	−0.751*
p-value	(0.000)	(0.017)	(0.000)	(0.000)
LREC	−1.571*	−0.319*	−0.955*	−0.466*
P-value	(0.001)	(0.00)	(0.000)	(0.00)
LY*LREC	−0.181*	−2.366*	−2.819	−3.213
p-value	(0.000)	(0.000)	(0.000)	(0.000)
Wald test	34.232**	-	-	-
p-value	(0.012)	-	-	-
Pseudo R^2/R^2	-	0.635	0.788	0.761

Note:*<0.01, **<0.05, ***<0.10.

economies, there is a negative connection with CO_2 emissions. The negative coefficient for the interaction involving economic growth and renewable energy use indicates that at higher levels of GDP, the emissions mitigation via renewable utilization further increases. The gain in renewable energy of an economic system occurs because of a rising economic trajectory, which creates more emission reductions (Kasperowicz, 2015). Given our results here, a successful emission control program will cut CO_2 emissions during the period of economic expansion, mostly using renewable energy (Adewuyi and Awodumi 2017).

4.2. Further discussions

The outcome from Table 5 revealed that for both E7 and G7 economies, there was an inverted U-Shaped EKC obtained from economic growth and its subsequent expansionary impact on the environmental quality of both blocs as obtained from the analysis. This suggests that when countries achieve a significant level of economic advancement, there is a non-linear link between income and environmental degradation, characterized by an inverted U-shaped pattern. It is however important to note that the Kuznets effect is stronger in the case of the G7 compared to that of the E7 based on the magnitude of the environmental cushioning effect at higher economic growth levels. Certain factors could have influenced this observed difference between the two blocs. We believe that the stronger Kuznets effects in the G7 case may be better attributed to growing technologies that enhance energy efficiency, energy conservation, and renewable energy. This is one of the better positions to justify the EKC credibility in line with the income growth trend as observed in the specific case of the G7 countries. This outcome is in line with that of Agozie et al (2022), Appiah et al (2023) and Gyamfi et al (2022).

Moreover, as for financial development, it was observed that there is a positive significant relationship with emissions, especially in the E7 countries. This shows that financial development increases emissions for the E7 countries as contrasted with the G7 case where the outcome reveals that financial development helps in the mitigation of emissions for the bloc. Financial development leads to a rise in economic activities that are often driven by fossil energy, which subsequently triggers environmental strain (Onifade et al. 2023b). Besides, financial sectors and markets in emerging economies are allocating resources to industries that cause pollution and investing in initiatives that are not environmentally viable. An additional factor that could explain this observed result for the E7 in particular may be linked to the issue of inadequate stringent regulatory measures against the finance of conventional energy, and the lack of support as well as directives to finance ecologically sustainable initiatives in the E7 nations. These findings align with the results reported by Ahmad et al. (2020) about Belt and Road countries, and Ahmad et al. (2021) regarding Japan. Nevertheless, the present outcomes diverge from the conclusions given by Shahbaz et al. (2018), who assert that FD enhances ecological quality. However, it is crucial to note that the discovery from the G7 economies holds great significance. This is because increased levels of financial liberalization in G7 nations attract inflows of more green investment. Consequently, this encourages investments in research and development (R&D), potentially resulting in improved energy-related efficiencies and subsequently reduced emissions. Moreover, it affirms the findings of Tamazian et al (2009), Shahbaz et al. (2018), Onifade & Alola, (2022) and Ohajionu et al (2022).

In a nutshell, it has been determined that the adoption of renewable energy sources has a substantial reduction effect on emissions in all the economies examined. Howbeit, the results also essentially indicate that the G7 economies have a higher coefficient compared to the E7 economies. This implies that the utilization of clean energy is linked to a quicker decarbonization trend as far as emissions in the former bloc are concerned than in the latter bloc. Overall, many studies have supported this subsequent observation (Dingru et al., 2023; Adebayo et al., 2022; Yu et al., 2022; Ofori et al. 2023). Through the implementation of technological advancements in the field of environmental conservation, numerous countries have successfully educated their citizens on the drawbacks of fossil fuels, adopted alternate sources of energy, and transitioned their manufacturing processes to more sustainable and eco-friendly technologies, such as renewable energy. The study's findings indicate that the expansion of renewable energy usage significantly improves long-term environmental conditions. To advance the globe toward a future where there is no net energy consumption, it is crucial to establish sources of energy that are environmentally friendly.

5. Conclusion, policy implications and limitation

5.1. Conclusion

As anthropogenic impacts in both advanced and emerging nations continue to expand, hazardous CO_2 emissions into the environment are being released, resulting in a significant variety of climate-related concerns. Global commitments from advanced economies as well as other economies, such as the United States, the United Kingdom, Japan, and China, are increasing to keep the average worldwide heat rise below 1.5°C since pre-industrial thresholds and achieve net-zero emissions by 2050.

Green energy advancements, as well as the financial industry, are believed to have a particularly important responsibility to play in the reduction of greenhouse gas emissions, alongside governments and global organizations. The influence of financial growth and renewable energy usage on the attainment of the 1.5°C and net-zero emissions target is investigated in the present analysis by employing heterogeneous methods including AMG and Quantile regression for the E7 and G7 economies from 1990 through 2019. The empirical analysis indicates that financial development has a negative effect on the environment of the G7 economies while it has a positive significant effect on the E7 economies. However, a significantly negative relationship is established between carbon emissions and clean energy utilization. Additionally, there was a validation of the EKC for both economies indicating the square of economic growth and the economic growth indicator exerting positive and negative effects on CO_2 emissions. Furthermore, a negative link is established between growth and renewable energy interaction and CO_2 emissions.

5.2. Policy implications

Following the outcomes of this analysis, we make some policy suggestions tailored to the G7 and E7 analytical findings. Firstly, according to the findings of the analysis, broader financial services from a rising financial sector growth has a negative environmental consequence as it increases anthropogenic carbon emissions, and this has been demonstrated especially in the E7 economies. Because of this, it is necessary to consider regulatory ramifications to induce a sustainable environment from a financial expansion perspective. Authorities in the E7 can create policies that encourage a positive and long-term influence on financial growth to support general planning and execution of emission mitigation targets. It is also advised that governments encourage financial initiatives and systems that may make a substantial contribution to eco-friendly projects to achieve greater success. This should include the designing of more efficient financial systems for adopting clean energy, leading to a greater yield in the sense of a greener lifestyle over the long run. Additionally, authorities in the G7 countries in particular need to re-strategize in developing their financial industries to promote private sector investment, as well as several other green steps to enhance ecological integrity.

Secondly, the adoption of renewable energy decreases CO_2 emissions for both economic blocs separately, as well as in their combined analysis. The development of renewable energy programs should be incorporated and further strengthened in global warming strategies, as well as the formulation and construction of geographic and multinational strategies and projects to assist the globe in its transformation toward a more efficient and environmentally friendly energy globe. In addition, to stimulate the deployment of renewable energy techs, authorities could provide tax breaks and eco-friendly financial subsidies to enhance tech solutions to emission challenges. A very recent study by Tarr et al. (2023) has revealed that such financial subsidies are crucial to support the use of technologies to attain desired goals in the ongoing global decarbonization campaign. Also, it is important to stimulate public-private partnerships to support the usage of such products. Climate-conscious legislators should implement favorable changes to their energy mix and implement measures that encourage the use of renewable power techniques such as wind and solar, which reduce CO_2 emissions.

Furthermore, global development toward lowering industrial CO_2 emissions and achieving the net-zero emission objective will continue to be dependent on the understudy countries' climate programs as well as global climate policy. As a result, the environmental agencies in both G7 and E7 blocs should implement better climate protection laws as well as strict emissions reduction objectives for fossil energy-dependent sectors that pollute the environment. Besides, authorities should establish strategies that will redirect their economies away from the use of fossil fuels. Climate-conscious politicians should set more aggressive decarbonization objectives, lay down smooth road maps for decarbonizing emission-intensive businesses, and impose obligatory environmental policy disclosure rules, among other things. This involves boosting the use of zero-emission cars and speeding up the move away from combustible engines.

Lastly, to meet the 1.5°C temperature objective and the net-zero emission threshold, authorities must strive to serve a crucial role in allowing entrepreneurs to explore innovative thoughts and assist the most promising opportunities to find a path to prosperity. The state financing of R&D is at the core of this endeavor, and authorities should expand financing for sustainable technologies as part of this endeavor. Similarly, authorities within the understudy countries must make bold and exceptional transformations in all parts of life, as well as measures that encourage the adoption of clean energy, to avert disastrous amounts of CO_2 emission.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix

Table A1. Descriptive statistics and correlation matrix.

	LCO_2	LFD	LY	LREC	LY*LREC	
E7 ECONOMIES						
Mean	13.578	3.775	8.493	2.942	25.288	
Median	13.105	3.873	8.952	3.065	27.434	
Maximum	16.153	4.5662	9.551	3.997	35.436	
Minimum	12.055	2.749	6.514	1.171	9.213	
G7 ECONOMIES						
Mean	2.297	4.770	21.179	4.355	46.127	
Median	2.245	4.727	21.182	4.421	46.722	
Maximum	3.004	5.399	21.814	4.550	48.875	
Minimum	1.520	4.068	20.479	3.833	40.761	
COMBINED ECONOMIES						
Mean	7.163	4.341	9.685	3.746	37.138	
Median	2.846	4.325	10.421	3.997	41.974	
Maximum	16.153	5.399	10.907	4.550	48.875	
Minimum	1.520	2.749	6.514	1.171	9.213	
CORRELATON						
E7 ECONOMIES						VIF
LCO_2	1.000					-
LFD	−0.790	1.000				0.510
LY	−0.885	0.677	1.000			0.264
LREC	−0.712	0.525	0.779	1.000		0.391
LY*LREC	−0.841	0.645	0.902	0.969	1.000	0.217
G7 ECONOMIES						
LCO_2	1.000					-
LFD	0.542	1.000				0.345
LY	0.363	0.651	1.000			0.243
LREC	0.4302	0.2671	−0.0254	1.000		0.421
LY*LREC	0.527	0.462	0.292	0.948	1.000	0.256
COMBINE ECONOMIES						
LCO_2	1.000					-
LFD	−0.137	1.000				0.267
LY	−0.334	−0.305	1.000			0.352
LREC	0.425	−0.424	0.387	1.000		0.489
LY*LREC	0.264	−0.451	0.611	0.964	1.000	0.478