Ecological-linked technology, institutional quality and environmental sustainability: Evidence from E7 economies

Author(s): Gyamfi, Bright Akwasi; Ofori, Elvis Kwame; Onifade, Stephen Taiwo; Alharthi, Majed; Prah, Stephen; Elheddad, Mohammed

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Ecological-linked technology, institutional quality and environmental sustainability: Evidence from E7 economies

Bright Akwasi Gyamfi
Faculty of Management, Multimedia University, 63100 Cyberjaya, Selangor, Malaysia
Email: brightgaymfi1987@gmail.com
Elvis Kwame Ofori
Department of Plants and Agribioscience, University of Galway, Ireland.
Email: oforikwamee@gmail.com
Stephen Taiwo Onifade
School of Accounting and Finance, Economics department, University of Vaasa, FI-65200, Vaasa, Finland
Email: stephen.onifade@uwasa.fi
Majed Alharthi
College of Business, Finance Department, King Abdulaziz University, Saudi Arabia
Email: majed@kau.edu.sa
Stephen Prah
Department of Agricultural Economics, Agribusiness and Extension,
Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
Email: stephenprah888@gmail.com
Mohamed Elheddad
Business Studies, Teesside University International Business School, Middlesbrough UK
Email: m.elheddad@tees.ac.uk

ABSTRACT

The COP-27 meeting held in Egypt in November 2022 aimed to build on past successes and set the foundation for future objectives in the fight against global warming. Achieving ecological responsibility remains a significant challenge, particularly in light of the Post-Glasgow Agreement goals, necessitating increased pressure on participating nations to act. Despite its importance, previous literature has inadequately explored the factors that effectively reduce carbon emissions in E7 economies. This study addresses this research gap by forecasting the impact of green environmental technology, technological innovation, renewable energy adoption, structural changes (measured by the contribution of services to GDP), and institutional quality (IQ) on carbon emissions in E7 economies. Using the advanced Method-of-Moments Quantile (MMQ) procedure on data from 2000 to 2020, the study finds that environmental technology significantly reduces carbon emissions, while technological innovation increases emissions within the bloc. Additionally, institutional quality, structural changes, and renewable energy adoption exhibit a significant inverse relationship with pollution levels. These findings underscore the importance of policies that restore and promote environmental technology while simultaneously fostering technical advancements. Such strategies are essential for achieving the United Nations' Sustainable Development Goals (SDGs) 7 (Affordable and Clean Energy) and 13 (Climate Action).

Keywords: COP-27, Technological innovation, E7 economies, Environmental technology, carbon neutrality, CO_2 emissions.

1. Introduction

Global warming and environmental degradation have emerged as major issues for both developed and developing nations (Ahmad and Zheng, 2021; Khan et al. 2022). In an effort to achieve economic growth, emerging economies have increased their use of fossil fuels and other energy sources in recent decades (Zhang et al. 2022). With major repercussions for ecosystems, wildlife, and human welfare, this increase has accelerated the emission of greenhouse gases (GHGs), causing severe disruptions in weather patterns, including earthquakes, hurricanes, tornadoes, and volcanic eruptions (Obobisa et al. 2022). Carbon dioxide (CO_2) is one of the main GHGs that contributes to pollution in both developed and developing countries. The use of solid, liquid, and gaseous fuels has caused CO_2 emissions to triple since 1960, making it a major challenge for world leaders to control (Ahmad and Zheng, 2021). As a result, developments in ecologically conscious technologies and the creation of institutional frameworks are now essential for reducing the negative impacts of CO_2 on the environment and human health while fostering sustainable global economic growth (Khan et al. 2022; Zhang and colleagues. 2022).

The notion of technological innovation related to the environment centers on creating new products and improving current products, processes, or organizational systems in order to lower energy consumption, minimize emissions of pollutants, improve environmental quality, and aid in the development of a greener economy (Ahmad and Zheng, 2021). In recent years, technological innovation has emerged as a key component in the fight against global warming. It has been shown in numerous studies to be a major force behind industrial transformation, fostering increased efficiency and quality in the contemporary era (Wang and Li, 2020). According to Raihan and Tuspekova (2022), technological innovation is also essential for economic restructuring and optimization. In particular, technological innovation pertaining to the environment has a greater positive influence on the environment than conventional technologies (Dong et al. in 2022). In addition to helping nations increase the efficiency of their production processes, these technologies help the environment by utilizing green energy and lowering dependency on fossil fuels. In order to combat climate change, they are essential (Zhang et al., 2016), expanding the green economy, and cutting CO2 emissions dramatically (Dong et al. in 2022).

In order to promote environmental protection, reduce CO2 emissions, and improve environmental quality, the caliber of institutions and technological innovations related to the environment are crucial (Obobisa et al. 2022). Researchers, economists, and policymakers are paying more and more attention to the significance of institutional quality in environmental issues (Salman et al. 2019). Because they support the rule of law, fight corruption, lessen military influence in politics, and improve public financial management, research shows that strong institutional frameworks are crucial for efficient environmental governance, policy implementation, and pollution control. However, low-quality institutions can have long-lasting detrimental effects on a nation's economic well-being (Hassan et al. (2020). Furthermore, the legal and cultural frameworks that support financial and socioeconomic activity are shaped by the quality of the institutions, which has a direct impact on initiatives to reduce pollution. According to Rizk and Slimane (2018), high-quality institutions are essential because they reduce the costs of economic growth, allowing nations to attain higher income levels. A strong rule of law and stringent regulations can force companies to reduce their CO2 emissions, underscoring the critical role that high-quality institutions play in lowering pollution and guaranteeing environmental sustainability (Asongu and Odhiambo, 2019).

According to some empirical studies, raising institutional quality could result in higher emissions of pollutants (Le et al. 2020), but some contend it's good for the environment (Xue et al. 2021). Abid (2017) and Amin et al. (2021) demonstrate how institutional elements that affect environmental policies and carbon-reduction plans include government regulation, efficiency, political stability, rule of law, and corruption. Financial efficiency is increased and transaction costs are reduced by efficient institutions. In order to fight corruption, enhance financial management, and improve environmental conditions, nations are attempting to establish robust and effective institutional frameworks (Obobisa et al. 2022). Based on Ahmad and Zheng (2021) and Ibrahiem (2020), a country's capacity to address environmental degradation depends on its institutions. Furthermore, to enforce laws and put forward bold plans to cut greenhouse gas emissions, developing nations particularly require stronger institutions (Hassan et al. Ahmad and Zheng, 2021; 2020). Policies such as feed-in tariffs, carbon taxes, and the elimination of fossil fuel subsidies are examples of how institutions affect environmental outcomes (Haldar and Sethi, 2021).

The objective of this study is to examine the impact of environmental technology and institutional quality on carbon emissions in E7 economies. The E7 group, comprising China, India, Brazil, Russia, Indonesia, Mexico, and Turkey, is projected to experience economic growth at nearly double the rate of the G7 advanced economies. By 2050, it is anticipated that six of the world's seven largest economies will be from the E7, with China projected to rank first, India second, and Indonesia fourth. Notably, China is expected to contribute 20% to global GDP by 2050, followed by India at 15%. A key challenge accompanying this economic growth is developing and adopting new green technologies to ensure long-term global growth that aligns with environmental sustainability goals. According to recent projections, China's carbon dioxide (CO2) emissions in 2050 are expected to decrease significantly, amounting to approximately 3.3 gigatonnes, or one-third of the emissions recorded in 2020. (PwC, 2017).

This study makes several contributions. First, it develops a taxonomy of green technology, categorizing it into environmental technology, efficiency-enhancing technology, and clean energy inputs, each critical to achieving carbon neutrality. Second, we introduce the concept of "green governance," emphasizing the importance of governance frameworks in driving sustainable development and aligning local policies with global climate goals. Second, it employs advanced econometric techniques, such as the Method-of-Moment Quantile Regression (MMQR), to capture the heterogeneity in cross-sectional data and provide more precise insights than traditional panel regression models.

This study is structured as follows: Section 2 presents a review of the relevant literature. Section 3 outlines the methodology, detailing the indicators and methods employed to address the research topic. Section 4 reports the findings. Finally, Section 5 provides recommendations and discusses policy implications.

2. Literature Review

As nations' worries about global warming increase, new interventions and policies are required. Because climate change results from human activity (business operations and everyday human consumption), ecological, green, and low-cost energy sources are necessary to prevent the negative environmental repercussions of fossil energy usage. Such efforts will need innovation and sound government policies (Abbas et al., 2022; Agrawal et al., 2022; Akanle et al., 2022; Alaimo & Maggino, 2020). Since the latter half of the 20th century, several studies have analyzed the linkage between emissions and economic growth in the literature on energy economics. Figure 1 illustrates carbon emissions trend for top nuclear energy countries. Few studies agree that technology and institutional quality can mediate the relation – since conventional growth models are considered detrimental to the environment. Following that, numerous factors, including technological innovation and institutional quality, have also been examined in recent research. Investigators and decision-makers from many fields look for methods and equipment to lessen the growing environmental effects and guarantee social sustainability. As such, they often explore technological innovation and, lately, infuse green governance. It is usually acknowledged that any transition would require policy initiatives under the governance framework. This set the central theme for our study. However, to further provide a review of prior literature, we propose two questions that are developed in our hypotheses. Firstly, how does ecologically linked technological innovation serve the objectives of carbon Neutrality in E7 economies? Secondly, does institutional quality help attain the objectives of carbon neutrality?

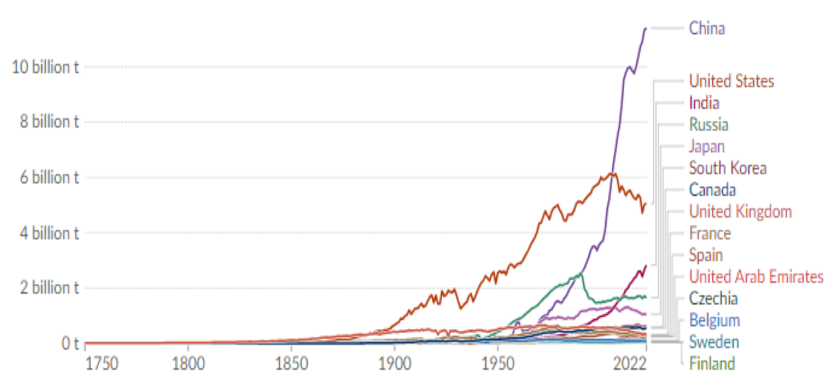

Figure 1. Carbon emissions trend for top 15 nuclear energy countries

Source: Global Carbon Budget, 2023.

2.1 Theoretical Underpinnings & Empirical Review of Innovation-Ecological Nexus

Schumpeter's famous endogenous growth theory (Alcouffe & Kuhn, 2004), which derives from growth theory, elaborates on how a process known as "creative destruction" is produced via innovative activities and promotes economic development (Carayannis et al., 2020). This objectively captures the core of economic development and goes further than the growth process portrayed by Solow's theory of external technological advancement (Diamond Jr., 2019). Furthermore, endogenous growth theories suggest a significant causal link between technical upgrades and economic expansion (Romer, 1994; Grossman and Helpman, 1994; Lucas, 1998).

Empirical research has multiplied since the creation of these ideas, in conjunction with well-established econometrics, to investigate the precise impacts of technological innovation on economic progress (Diamond Jr., 2019; Wang et al., 2023). As such, a particular focus has been placed on the environmental disruption caused by growth-related byproducts like carbon and solid waste (Habib & Iqbal, 2022; Kaur et al., 2023) and how innovation may be used to address the environmental disruption ascribed to growth. This leads to queries about what technological advancement is required to provide the necessary relief to save the ecology. This question is answered by Tietze et al. (2011). He posits that the phrases "environmental innovation," "eco-innovation," and "green innovation" have all been used interchangeably. As a result, ecologically linked innovation was the point of view in three ways for our study's objective. 1) As ecological innovation is specifically related to helping reduce the woes of the environment, 2) Efficient technology, which is innovation to replace conventional production –resulting in sustainable production (low carbon production 3) Efficient energy input is defined as renewable energy, which has a low carbon component, such as solar.

2.1.1 Green technology and Environmental Sustainability

According to Acemoglu et al. (2012), there are two different categories of technologies. They categorize technologies that harm the environment or add to its load as "grey technologies," while those that benefit the environment or address pollution issues are referred to as "green technologies." The latter is now a popular topic for scholarly study since it is thought to be an efficient strategy to balance the link between economic development and CO_2 emissions (Ahmed et al., 2022; Jahanger et al., 2022; Ikram et al., 2021; Li et al., 2021). However, there is no universal agreement among the pertinent research on how green technology advancements and environmental quality relate to one another. The CO_2 reduction impact of green technology has been shown to range dramatically across various economies. Innovative green technologies have significantly decreased emissions in industrialized economies (Chen et al., 2022; Boujedra et al., 2024; Du et al., 2019; Jahanger et al., 2022). According to Xu et al.'s (2021) study, heterogeneous green technologies have a favorable impact on carbon emission performance in Chinese cities. Green technologies did not have a major influence on the decrease of CO_2 emissions in Italy, according to Weina et al. (2016).

Although it is theoretically assumed that the more climate-related technologies there are, the better it will be to tackle climate change, there are relatively few practical examples to back this up (Su & Moaniba, 2017). According to several earlier studies (Acemoglu et al., 2012; Buonanno et al., 2003; Jiakui et al., 2023; Jahanger et al., 2022; Zeng et al., 2022), the impact of green technology advances on CO_2 emissions might vary depending on the situation and can also be impacted by several variables, including location, time, and industry. Braungardt et al. (2016) show that even though green innovations are often seen as a crucial component of a strategy for green development, their influence on climate objectives has been the topic of a protracted discussion because of the presence of the rebound effect.

Green technologies are predicted to be a significant contributor, potentially contributing to more than 60% of the projected carbon emission reductions in the International Energy Agency's (IEA's) 450 scenarios (IEA 2009; Chen et al., 2022). More crucially, green innovation (i.e., innovation linked to environmentally sound technologies (ESTs)) may concurrently enhance firm productivity and the beneficial spillover effects of ecological sustainability (Guo et al., 2018), potentially improving carbon emission management.

2.1.2. Clean Energy Inputs and Sustainability

Environmental deterioration is a new-century problem (Mahjabeen et al., 2020; Belaid et al., 2021b). To solve this dilemma, the green energy transition represents a last-ditch challenge for governments to provide a stable energy supply while also improving environmental quality (Bhattacharya et al., 2017; Belaid et al., 2021c). The role of green energy in alleviating environmental deterioration has been thoroughly researched in a variety of countries and economies. Prior research has noted that decreasing and increasing the quantities of non-green (unclean) and green (clean) energy consumption, respectively, is necessary to address climate change issues, particularly about CO_2 emission reduction (Hu et al., 2022; Khan et al., 2022). However, the introduction of pertinent technologies is necessary to start this compositional change in the energy mix (Khan et al., 2022; Belal et al., 2020), so that green energy may be generated and delivered at comparatively lower prices compared to the expenses connected with the current non-green forms of energy. Investment in the development of green energy is thus seen as contributing to the restoration of environmental wellbeing.

Intuitively, we anticipate green innovation leading to carbon neutrality through four mediation pathways. To begin, green innovation may influence carbon emission performance through energy consumption architecture. This is because green innovation may enhance energy usage efficiency (Paramati et al., 2022) and encourage the replacement of fossil fuels with cleaner fuels (Yang Wang et al., 2022) in the manufacturing process, hence improving carbon emission performance (Du & Li, 2019). However, since fossil fuels are still predominantly the primary source of energy, their impact may be gradual but still necessary (Su & Ang, 2015; Boujedra et al., 2024). In contrast to the preceding literature, several research studies use econometric tools to investigate the impact of technological improvements on environmental performance (Abbas et al., 2022; Chen et al., 2022; Kunapatarawong & Martínez-Ros, 2016; Mohsin et al., 2022; Nikzad & Sedigh, 2017; Pang et al., 2022; Peng et al., 2022). In this regard, academics offered several measures as proxies for technological development, which may be redundant or lead to data bias. However, our research provides a broader perspective, delving into the implications of each technological innovation for end users and policymakers.

2.1.3. Institutional Quality and Sustainability

Governance, as a multifaceted concept to be captured in an index, may be characterized by a variety of aggregated indexes, each of which portrays a distinct component (Rafei et al., 2022; Halkos & Tzeremes, 2013). According to Halkos and Tzeremes (2013), governance quality has a critical role in shaping public choice, and it is especially important in environmental quality laws. Thus, institutions have a significant role in shaping public opinion (Ji et al., 2022), and as a result, they are crucial to the adoption and enforcement of laws governing ecological integrity (Debbarma & Choi, 2022). Essentially, governments decide how to handle natural resources in accordance with regulations (Akbar et al., 2022); hence, excluding institutional quality when estimating environmental quality might provide inaccurate findings (Debbarma & Choi, 2022; Rafei et al., 2022; Yang et al., 2022). The bane on the environment has frequently been income, and Bhattarai and Hammig (2001) argue that institutional factors have an impact on the income-environment relationship via the efficacy of the implemented policy, and that such pervade the notion of "green governance."

The two primary reasons for reviewing the relationship between governance and sustainable development are (i) the current concern about environmental pollution and (ii) the problems with weak governance associated with the management of the policy syndrome of environmental pollution. The next paragraphs provide a chronological expansion of the causes. The first strand, which is similarly based on the possibility of accelerating development to reduce pollution under key criteria, ceteris paribus, is based on a weak governance approach towards the transition to clean energy or accessing the policy execution of the environmental Kuznets curve (Ofori et al., 2023). The second notion is also leveraged by Ofori et al. (2023), who argue the need for governments to decide which policies will provide funds for clean energy research and the creation of a playbook for green finance. Environmental governance laws need to be considerably updated in order to go beyond accords and summits and incorporate practical activities like supporting environmental initiatives (Arney et al., 2022). Also, most enterprises are either private or public; they operate within an enclave with rules and regulations, and the deficit of biodiversity loss cannot be disregarded; government intervention is required for green growth to be realized.

3.0 Methodology and Data

3.1. Data acquisitions

The present research builds a balanced panel of seven rising economies using 20 years of yearly time series data from 2000 to 2020 for empirical examination. Using a sample from 2000 to 2020 strengthens the study's validity by capturing long-term trends, significant policy developments, technological advancements, and economic cycles that influence emissions and renewable energy integration. The selection of the sample was based on UN-SDG 13's goals and how those goals may be achieved via technology, which are UN-SDG 7 and 9. Environmental degradation is quantified in metric tons per capita in the multivariate framework of the current research using CO_2 emissions, while innovation is measured in three ways. Technology related to the environment, renewable energy, and efficiency is governed by institutional quality and service value added. All of the study's series' data sources as seen in Table 1 are taken from the World Bank. Except for institutional quality, all of the variables have undergone a normal logarithmic shift to activate stationarity characteristics and avoid problems with distributional features. All the variables are presented in Figure 2.

The Understudied Variable(s)	Indices	Source
CO_2 emissions (viewed in kg per 2015 US$ of GDP)	EP	WDI
Environmental Technology (all environmental patents)	ENVTEC H	OECD
Renewable energy consumption (% of final consumption)	Ren	WDI
Technological innovation (sum of patent resident and non-residents)	TI	WDI
Institutional Quality (Index)	IQ	WGI
The services, value added (viewed in constant 2015 US$)	SER	WDI

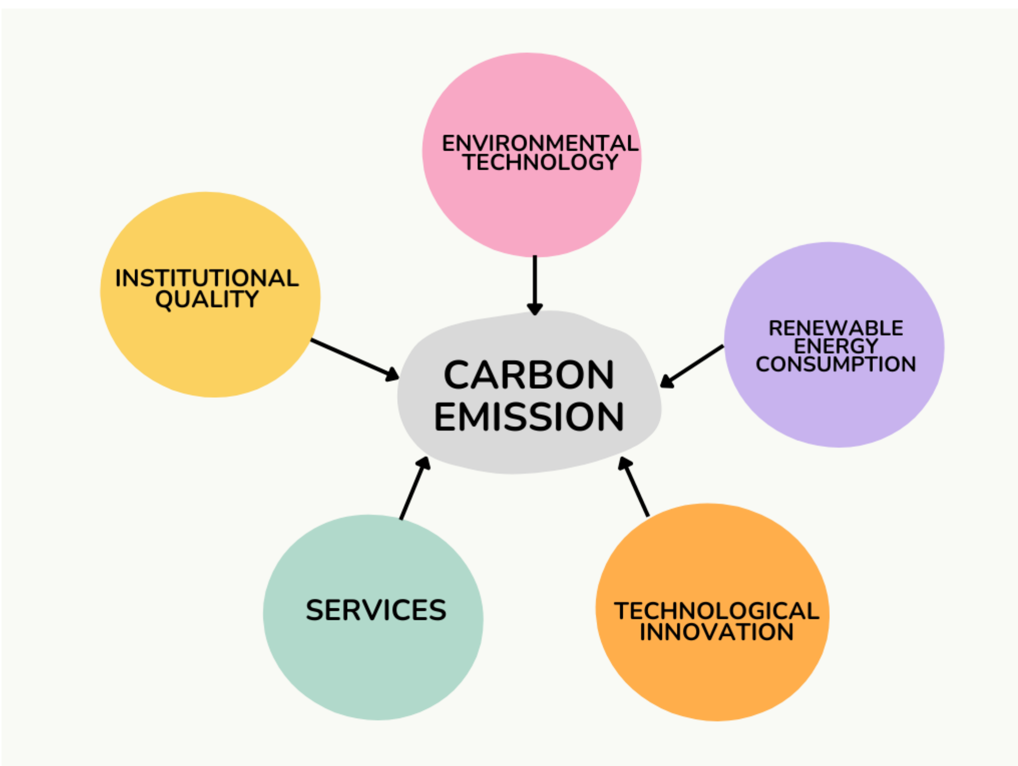

Figure 2. Variables used in the model

3.2. The Institutional Quality Indices

A principal component analysis (PCA) was developed for governance quality. Often, the choice of indexes to describe institutional quality becomes difficult because different economies have different parameters for governance indexes that hold true for them. For example, corruption and political stability would be at the forefront of governance indicators in a developing country like Africa, but they are less prominent in advanced countries like the United States. Governance effectiveness will be their priority. However, in our case, we took the perspective of using a composite, which also helps reduce the noise of single variables or data bias. So, we employ Principal Component Analysis (PCA**).** PCA is a method for building an index from a set of variables with informational similarities. This enables us to maximize the information we retain without employing variables that will lead to multicollinearity or needing to pick a specific variable from many options**.** Below are the steps leading to the prediction of the index and scree plot in Figure 3.

Table 2. Principal components/correlation

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.9660	1.7800	0.4940	0.4940
Comp2	1.1860	0.3080	0.1980	0.6920
Comp3	0.8770	0.2760	0.1460	0.8380
Comp4	0.6010	0.3600	0.1000	0.9380
Comp5	0.2410	0.1110	0.0400	0.9780
Comp6	0.1300		0.0220	1.0000

Table 3. Principal components (eigenvectors)

Factors	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Unexplained
controlofc~e	0.530	-0.029	-0.113	0.178	-0.665	0.481	0.000
government~e	0.429	-0.397	-0.413	-0.182	0.601	0.306	0.000
politicals~i	0.258	-0.449	0.706	0.446	0.175	-0.068	0.000
regulatory~e	0.436	-0.037	0.295	-0.746	-0.169	-0.370	0.000
ruleoflawe~e	0.466	0.279	-0.340	0.424	0.070	-0.636	0.000
voiceandac~e	0.249	0.749	0.341	-0.016	0.363	0.358	0.000

Scoring coefficients-sum of squares(column-loading) = 1

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6
controlofc~e	0.530	-0.029	-0.113	0.178	-0.665	0.481
government~e	0.429	-0.397	-0.413	-0.182	0.601	0.306

politicals~i	0.258	-0.449	0.706	0.446	0.175	-0.068
regulatory~e	0.436	-0.037	0.295	-0.746	-0.169	-0.370
ruleoflawe~e	0.466	0.279	-0.340	0.424	0.070	-0.636
voiceandac~e	0.249	0.749	0.341	-0.016	0.363	0.358

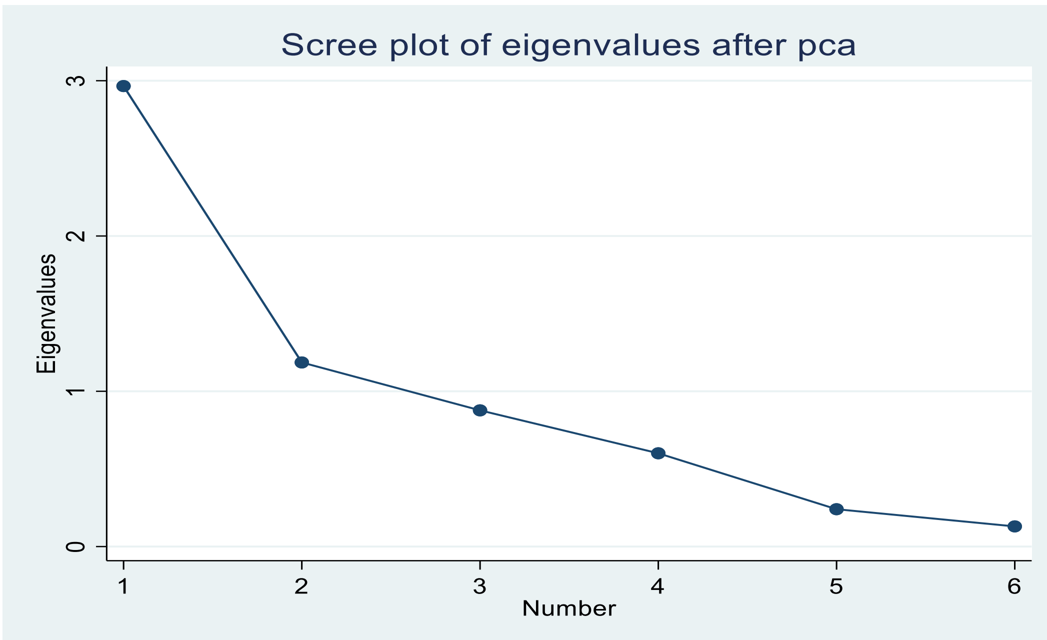

Fig 3. Scree plot

3.3. Model Development

Multiple estimators have been employed for the objectives of empirical analysis in the current investigation. Different methods have come in handy in helping shape policies while utilizing panel data with finite temporal dimensions, and endogeneity problems are also controlled. However, there are a few drawbacks since distributional impacts and heterogeneity are not captured in the adopted procedures. Therefore, a method that can aid in the exploration of the quantiles was required due to the limitations of these basic and historical estimators (Wheeler, 1980). The quantile regression method was initially developed in the context of panel data by Koenker and Bassett (1978). Typically, quantile regression is used to calculate the variance and divergence among the criteria variable's quantiles (CO_2 emissions in our case). In contrast, the parameters were calculated using OLS regressions on the other side of the independent variables. Additionally, the quantile regression method has the advantage of being flexible and resilient in the presence of outliers in the data. Additionally, this method is thought to be more appropriate when the conditional averages of the relationship between two variables turn into statistically inconsequential conditions (Binder & Coad, 2011).

Additionally, (Machado & Silva, 2019; Sun et al., 2022) presented the Method of Moments Quantile Regression, a fixed effect variation of the panel quantile estimation method (MMQR). Although the quantile regression's robustness in the presence of outliers is well established (Koenker & Bassett Jr., 1978), the approach is unable to account for the panel dataset's undiscovered heterogeneity among its cross-sections. In contrast to traditional approaches, which only change averages, this procedure has the advantage of evaluating the covariance effects among CO_2 emission indicators and its differing boolean heterogeneity, which stipulates the specific relationship and results in the overall behavior of the data. Additionally, this test yields genuine findings when the predictor variables exhibit endogeneity, and it also yields legitimate results when a specific impact tends to outweigh the dataset's overall variance. (Usman & Jahanger, 2021) Because quantiles are generated under overlapping estimation circumstances, this approach produces more insightful findings (Canay, 2011).

Equation 1 represents the estimations of the scale variant's conditional quantiles $Q_y(\partial/X)$ in the appropriate region.

$$Y_{it} = \emptyset_i + X_{it}^{\iota}\beta + (\varphi_i + Z_{it}^{\iota}\gamma)U_{it} \tag{1}$$

It is necessary to evaluate the parameters and probability $P\{\emptyset_i + Z_{it}^{\iota}\gamma > 0\}, (\alpha, \beta^{\iota}, \phi, \gamma^{\iota})^{\iota}$,with reference to equation (1). ι stands for the specific fixed impact of the entity, which $(\emptyset_i \varphi_i), \iota = 1, \ldots .n$. In contrast, for the sections of X and its related k-vectors that are known, is powered by Z that are truly the transitions that are discrete while having the components ι, as shown below, the specific fixed impact of the individual is indicated by

$$Z_{\iota} = Z_{\iota}(\chi), \iota = 1, \ldots \ldots, K \tag{2}$$

It should be observed that the distribution of $\chi_{it}$for each specific I time is same and independent (t). Similar to how the distribution of μ_{it} is probably represented for specific people I period (t) that exhibit generalizability of meeting the requirements that are transient and are not constrained by the patterns of the researched predictors, while they are also orthogonal to, as a result, Eq. (1) is presented with a modification as Eq (3).

$$Q_y\left(\frac{\upsilon}{X_{it}}\right) = \left(\alpha_i + \delta_i(\tau)\right) + \chi_{it}^{\iota}\beta + Z_{it}^{\iota} \tag{3}$$

The matrices of the predictor variables are shown in Eq. (3), in which all variables under investigation have been standardised using the natural log. Additionally, the coefficient at a scalar, which is the scaled version of the specific individuals I at the period (t) of the fixed effect, is denoted by, and the variation of the quantiles of the path coefficient is denoted by, whereas the natural log of the coefficient of determination is denoted by, which is subject to the location of the predictor variables. Additionally, there has been no change recorded in the individual intercepts, which are often seen in fixed traditional least-squares-based estimates. While the estimated parameters' impacts and their corresponding fluctuation are heterogeneous in nature and capable of deviating depending on the circumstances of the quantile distribution of the criteria variables, they are not time-sensitive. By supporting the optimization of the result, the quantile of the sample is represented and subsequently calculated.

$$Q_y\left(\frac{\tau}{X}\right) = \left(\alpha_i + \delta_i(\tau)\right) + X_{it}^{\iota}\beta + Z_{it}^{\iota}\gamma q(\tau) \tag{4}$$

Where, X_{it}^{ι} denotes a vector of independent factors including enhanced innovation, institutional quality, renewable energy, environmental technology, and energy efficiency. $Q_Y(\frac{\tau}{X})$ asserts that the dispersion of structural quantiles for the dependent variable Y_{it} (CO_2 emissions) depends on the location (distribution) of exogenous variables X_{it}. The scalar coefficient labelled as $\alpha_i(\tau) = \alpha_i + \delta_{iq}(\tau)$ illustrates individual i quantile of fixed effects. In contrast to the conventional fixed least-squares effects, intercept shift does not reflect the individual impact. Such parameters might diverge along the conditional locational quantiles of the endogenous variable since they are time-invariant and have diverse effects. By tackling the resultant optimization issue expressed in equation (5), the sample quantile denoted by $q(\tau)$may be evaluated.

$$minq = \sum_i \sum_t p_\tau (R_{it} - (\delta_i + Z^{!}_{it}\gamma)q) \quad (5)$$

4. Outcomes and Discussions from the Analysis

4.1. Discussion of Preliminary Tests

This section pertains to the empirical results of the investigation, encompassing the summary statistics and correlation coefficient analysis. The fundamental measurements of the coefficients being examined are presented in Table 4. The study revealed that, except for structure changes, which exhibited positive skewness, all other variables demonstrated a negatively skewed analysis range. Regarding the peaks of the dataset, as denoted by Kurtosis, it is noteworthy that only the environmental tax variable exhibits a significantly heavy tail, whereas the remaining variables, namely emission, service-added change, environmental technology, renewable energy, technology innovation, and institutional quality, all display light tails. When the Jarque-Bera likelihood function is not rejected, it indicates that the normality assessment of all series shows that they are normally distributed, which is a favorable outcome. Additionally, the variance inflation factor (VIF) indicates the absence of multicollinearity among the chosen coefficients. Environmental technology, renewable energy, and structure change (service added) were positively correlated with emissions, while technology innovation and institutional quality were negatively correlated with emissions, according to the correlation analysis presented in Table 5. However, it is important to note that there is criticism of the Pearson correlation assessment, thus necessitating further econometric analysis. This matter will be addressed in the subsequent phase of the ongoing examination.

Table 4. Descriptive Statistics

Factors	Observ	Mean	LnMean	Std. Devi.	Mini.	Maxi	Skew	Kurt.	VIF	Jarque-Bera test
LnEP	140	0.749	-0.434	0.583	-1.510	0.694	-0.175	1.935	1.256	0.2256
LnENVTECH	140	27.29	4.278	1.822	-0.693	8.684	-0.088	3.136	0.643	0.1198
LnREN	146	59.68	10.033	1.533	6.73	14.253	-0.773	3.998	0.543	0.2109
LnTI	140	24.40	2.839	0.867	1.157	3.89	-0.556	2.247	0.987	0.1538
IQ	140	3.30	0.112	1.722	-4.215	2.815	-0.452	2.388	0.123	0.1270
LnSER	147	162.12	27.275	0.846	25.665	29.685	-0.881	3.932	0.653	0.3262

Normality test of the error terms										0.3623 (p=0.1269)

Table 5. Correlation analysis

	LnEP	LnENVTECH	LnREN	LnTI	IQ	LnSER
LnEP	1.00					
LnENVTECH	0.219*	1.00				
LnREN	0.410***	0.741***	1.00			
LnTI	-0.418***	-0.0709**	-0.172*	1.00		
IQ	-0.622***	0.0508**	-0.177*	0.374***	1.00	
LnSER	0.148	0.745***	0.929***	-0.095**	0.0841**	1.00

Note: ***, ** and * stands for significance at 0.01, 0.05 and 0.10 level, respectively

The present study analyzes the CD data series using various statistical approaches, including LM method (Breusch & Pagan, 1980) and the scaled LM (Pesaran; 2015). Others like the Pesaran (2007) CD were also used and corroborated by the Bias-corrected scaled LM methods. Table 6 displays the results of the assessments. The research findings indicate that, at a significant level of one percent, there is a rejection of the null hypothesis that there is no cross-sectional correlation in all four tests for all factors in E7 economies. According to the Pesaran-Yamagata (2008) SH technique presented in Table 7, it can be concluded that the null hypothesis of SH is rejected with a significance level of one percent. This implies that any subsequent econometric analyses must exhibit resilience in addition to CD and SH.

Table 6. Cross-sectional dependence technique outcomes

	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
LnEP	166.181***	21.093***	22.909***	8.791***
LnENVTECH	32.487***	10.805***	10.680***	6.758***
LnREN	225.363***	31.534***	31.359***	14.521***
LnTI	120.872***	15.411***	15.236***	10.400***
IQ	184.893***	25.289***	25.105***	-20.918***
LnSER	408.212***	59.748***	59.573***	20.193***

Note: *** represents the significance at 0.01 level

Table 7. Slope heterogeneity (SH) Method

Test	Value	P-value
$\tilde{\Delta}$	5.675***	0.000
$\tilde{\Delta}_{adjusted}$	7.156***	0.000

Note: *** represent the significance at 0.01 level

The econometric analysis conducted using Pesaran's (2007) CIPS and CADF unit root techniques (refer to Table 8) indicates that all factors are stationary at the first difference. Additionally, based on the results of the cointegration analyses presented in Table 9 (Westerlund, 2007; Kao Residual Cointegration Test), it is evident that there exists a sustained relationship between the variables over an extended period. Both methodologies demonstrate a null assumption that is rejected at a 1% level of significance, thereby indicating the presence of cointegration among the factors for both methods.

Table 8. Panel Stationarity technique

	CIPS		CADF	
	Level	1st Diff.	Level	1st Diff.
LnEP	-1.448	-2.717***	2.390	-2.817***
LnENVTECH	0.530	-5.455***	0.580	-2.920***
LnREN	-1.237	-3.599***	1.427	-4.801***
LnTI	-1.944	-3.723 ***	-0.503	-5.120 ***
IQ	-0.455	-3.330***	3.560	-4.109***
LnSER	-1.841	-3.934***	-0.221	-5.662***

Note: *** represents the significance at 0.01 level

Table 9. Cointegration Test

Kao cointegration	t-Statistic	P-value
ADF	-3.567***	0.001
Residual variance		0.001
HAC variance		0.002
Westerlund cointegration		
Variance ratio	-4.456***	0.001

Note: *** represents the significance at 0.01 level

4.2. Long-run Findings and Discussions

Table 10 presents the initial value regression analysis that examines the impact of environmental green technology, structural change (service added), renewable energy, technology innovation, and institution quality on the carbon dioxide (CO_2) emissions of E7. The Method of Moment Quantile (MMQ) regression techniques, as cited in Koenker (2004) and Canay (2011), offer an advantage by enabling the assessment of carbon emission outcomes of determinants and other likely heterogeneities. This facilitates the establishment of a specific connection and relates to the overall attitude of the data, which conventional methods achieve solely by adjusting the averages. Moreover, this test produces reliable outcomes in the presence of endogeneity in the dependent variable, and it generates reliable outcomes when a particular impact endeavors to surmount the general variation in the dataset. Therefore, the approach yields more informative results due to the generation of quantiles in the overlapping assessment scenarios and was implemented as the fundamental methodology. Moreover, the fixed effect, random effect, and the Driscoll-Kraay OLS were used to add robustness to the MMQ. The Wald test statistic of 1130.1 (p-value=0.000) indicates a significant result, suggesting that the estimated coefficients in the model are significantly different from zero. This implies that the effect or relationship being tested is statistically significant and not likely due to random variation. From the MMQ analysis presented in Table 9, it was observed that there is a negatively significant linkage between environmental technology and carbon emissions for the E7 economies. This observation demonstrates that the advancement of environmental technology in the E7 economies leads to a decrease in emission levels within these countries, corroborating the conclusions drawn by Sharif et al. (2022), Dong et al. (2022), and Hussain et al. (2022). Carbon emission efficacy in businesses will improve as a result of increased production scale, output, and decreased energy usage, driven by the proliferation of environmentally friendly green technologies. Since the E7 economies have exhibited a marked increase in their production of products over the last two decades, and additional growth is also projected, this conclusion translates to the continued appeal of highly efficient green technology investments. To this end, E7 may help bring about a more sustainable environment by increasing its investments, especially in the energy-efficient, resource-conserving technology (ERT) of manufacturing and processing.

Meanwhile, technological innovation is perceived to have a significant positive connection with emissions for the E7 economies. This implies that, as technological innovation increases within these countries, emission levels within the countries also increase across all the quantiles. Total effect-wise, the finding is in line with the view of Churchill et al. (2019), who argue that advanced technical innovation can greatly decrease CO_2 emissions. The rationale could be that the scale of manufactured goods on the global market would expand greatly if a country achieved swift industrialization thanks to high-level technological innovation, which would subsequently reduce ecological degradation produced by manufacturing in comparable countries. In line with Churchill et al.'s (2019) main hypothesis, low-tech countries may not benefit from ecologically favorable spillovers, and their ecological health may even be adversely harmed by the low degree of technical advancement in surrounding countries. The results show that the E7 countries are not likely to reduce their CO_2 emissions through technological innovation. This is probably because the E7 countries are more willing to make trade-offs that hurt the economy or the environment to grow their economies. Moreover, this outcome is in line with Mughal et al.'s (2022) findings for South Asia and Chen and Lee's (2020) findings for cross-country evidence. The observed outcome is a cause for concern, and it is imperative for policymakers to promptly assess this occurrence within the E7 regions.

The research indicates that there exists a statistically significant inverse correlation between the use of renewable energy sources and carbon emissions, across all quantiles. A decrease in emissions for the E7 economies is observed because of a percentage change in renewable energy. The utilization of clean energy as opposed to polluting energy sources such as fossil fuels is a viable approach to mitigating the environmental impact. The present study's results align with those of Gyamfi et al. (2021) regarding E7 economies and Bekun et al. (2019) regarding EU countries. Specifically, both studies suggest that the expansion of renewable energy sources is associated with a decrease in ecological degradation. However, institution quality also improves environmental quality, as the analysis obtained shows. Hypo theoretically, this is the expected outcome of IQ on carbon emissions. How institutions aid ecological integrity can be explained in a variety of ways. There will be less pollution if the quality of institutions is excellent, as this means that corruption has been curbed, rules are effective, and the rule of law promotes environmental awareness among the general public and environmental advocacy groups. Therefore, it is recommended that environmental legislation be made more stringent. More people are aware of the problem of ecological pollution, and stricter laws are being enforced, which leads to less pollution. Economic freedom and market economies, which are fostered by a higher IQ, in turn improve ecological integrity. Moreover, it demonstrates a difference to the value of human life and the rule of law. Institutional support for green energy technology deployment and robust regulatory enforcement go hand in hand. These results confirm the empirical evidence of Bekun et al. (2021), Rafei et al. (2022) and Appiah et al. (20220). They hypothesized that in E7, CO_2 emissions might be drastically cut if IQ measures like preventing corruption, improving regulations, and establishing the rule of law were put into place. According to the results, these factors have a marginally positive impact on atmospheric efficiency and lead to subpar outcomes from government policy. The empirical evidence supporting the argument that affective components increase the stringency of ecological standards and, consequently, decrease pollution is provided by the findings that regulatory quality greatly restricts the expansion of CO_2 emissions.

In addition, it can be observed that there is a statistically significant negative correlation between carbon emissions and structural changes across all quantiles. The aforementioned result implies that the implementation of structural modifications within the E7 region leads to a decrease in carbon dioxide emissions. The economic significance of a structural transition lies in its ability to facilitate a country's shift from a low-polluting agricultural sector to a high-polluting secondary industry, followed by a subsequent transition to a less polluted tertiary sector. The rise in the service sector within the E7 economies is a predictable outcome. Based on the findings, the economy of E7 is primarily oriented towards services and has exerted a substantial influence on the worldwide gross domestic product in recent times. The service industry encompasses transportation, retail, and education among others. The service industry's environmental impact in the E7 aligns with anticipated outcomes, given its comparatively lower energy consumption in relation to other industries. Adebayo et al. (2022) conducted investigations that yielded comparable outcomes but on different premises.

Table 10. Method Of Moments Quantile Regression with Fixed Effects

	Location	Scale	MMQ1	MMQ2	MMQ3	MMQ4	MMQ5	MMQ6	MMQ7	MMQ8	MMQ9
LnENVTECH	-0.003**	-0.001***	-0.006**	-0.005***	-0.007***	-0.007***	-0.008***	-0.009***	-0.013**	-0.011*	0.012*
	(-1.44)	(-1.130)	(-2.35)	(-2.64)	(-2.88)	(-3.26)	(-3.26)	(-2.69)	(-2.21)	(-1.82)	(-1.37)
LnTI	0.048**	0.001**	0.049*	0.049*	0.049*	0.048**	0.048**	0.048**	0.047*	0.047*	0.047*
	(-1.070	(-0.06)	(-1.47)	(-1.71)	(-1.92)	(-2.31)	(-2.47)	(-2.17)	(-1.88)	(-1.62)	(-1.31)
LnREN	-0.398***	-0.034**	-0.349***	-0.360***	-0.369***	-0.383***	-0.399***	-0.415***	-0.426***	-0.435***	-0.449***
	(-4.09)	(-0.76)	(-4.25)	(-5.15)	(-5.92)	(-7.41)	(-8.30)	(-7.70)	(-6.87)	(-6.12)	(-5.16)
LnIQ	-0.019***	-0.004**	-0.014*	-0.015*	-0.016**	-0.018***	-0.019***	-0.021***	-0.022***	-0.023***	-0.025**
	(-2.28)	(-0.850)	(-1.48)	(-1.89)	(-2.26)	(-3.00)	(-3.56)	(-3.46)	(-3.18)	(-2.90)	(-2.54)
LnSERser	-0.442***	-0.014	-0.422***	-0.427***	-0.430***	-0.436***	-0.442***	-0.449***	-0.453***	-0.457***	-0.462***
	(-2.9)	(-0.32)	(-6.10)	(-7.23)	(-8.21)	(-10.05)	(-10.99)	(-9.91)	(-8.69)	(-7.62)	(-6.30)
No. of Obs.	132	132	132	132	132	132	132	132	132	132	132
R-Squared			975.98***	975.83***	977.13***	975.88***	976.76***	975.32***	975.12***	974.87***	976.76***
F/Wald test	1130.1***	1130.05***	1130.12***	1130.11***	1130.06***	1130.26***	1130.38***	1130.14***	1130.06***	1130.26***	1130.05***

Note: ***, **, and * stands for significance at 0.01, 0.05, and 0.10 levels, respectively

The fixed-effect OLS, random-effect OLS, fully modified OLS, dynamic OLS, and Driscoll-Kraay OLS techniques are used for robustness checks, and their outcomes are like that of the baseline technique for the analysis. Table 11 shows that environmental technology, renewable energy, intelligence, and structural change all have a negative significant relationship with carbon emissions. This implies that these variables enhance emissions while technological innovation, on the other hand, increases pollution within the E7 economies.

Table 11. Robustness check analysis.

	FE OLS	Driscoll-Kraay	Random effects	FMOLS model	DOLS model
LnENVTECH	-0.018**	-0.012**	-0.010**	-0.126***	-0.245***
	(-2.33)	-0.78	(-2.48)	(0.037)	(0.092)
LnTI	0.048**	0.582***	0.055**	0.023**	0.027**
	(-2.09)	(-3.85)	(-2.34)	(0.011)	(0.012)
LnREN	-0.398***	-0.145***	-0.373***	-0.036***	-0.038***
	(-6.63)	(-5.32)	(-6.35)	(0.016)	(0.014)
IQ	-0.019***	-0.053	-0.019***	-0.078***	-0.091***
	(-3.04)	(-1.33)	(-2.91)	(0.015)	(0.026)
LnSER	-0.442***	-0.933***	-0.437***	-0.406***	-0.109***
	(-11.91)	(-3.64)	(-11.57)	(0.089)	(0.028)
Constant	12.263***	19.562***	11.998***	-0.524**	-0.484***
	(-12.21)	(-3.56)	(-11.70)	(0.235)	(0.187)
Observations	132	132	132	132	132
R-Squared	0.751	0.638	0.698	0.7231	0.5911
F Statistic	72.186***	72.155***	74.134***	61.17***	52.46***

Note: ***, **, and * stands for significance at 0.01, 0.05, and 0.10 levels, respectively

5.0 Conclusion and Policy Recommendations.

5.1 Conclusion

As the globe struggles to find solutions to the problem of climate change, there has been a surge in support for spreading the word about and investing in environmentally friendly technological breakthroughs. Specifically, the swift economic expansion in numerous large emerging economies has shifted the emphasis to the relevance of green technological advances in enhancing carbon efficiency, one of the main priorities in improving individuals' quality of life without contributing to climate change. The nations that attended COP 27 in Egypt in November 2022 seek to address ecological concerns. To this end, this study examines the effect of environmental technology, technological innovation, institution quality, structural changes, and renewable energy intake on carbon emissions for the E7 economies from 2000 to 2020. Thus, our research sought to address the question, "Can clean and green (environmental technology) produce sustainable development and aid in the achievement of UN-SDG goals?" 1, 3, 4, 8, and 13. A series of pilot tests are used in the study to limit the effect of cross-sectional correlation and make sure the results are accurate. Unlike previous studies, this one employs the “method of moment quantile regression" (MMQ) as the base line technique, which considers the panel's fixed effects. Moreover, we also used the fixed-effect OLS, random-effect OLS, and Driscoll-Kraay OLS for robustness confirmation.

From the empirical analysis, it was revealed that green environmental technology decreases emission levels within the E7 economies. Moreover, technological innovation, on the other hand, enhances emissions within these economies. Furthermore, as expected and confirmed by the hypothesis, renewable energy, institutional quality, and structural change (service added) all decrease ecological pollution within the E7 economies. The diverse outcomes pose challenges for a developing nation. The incongruous results are a matter of concern for policymakers in the E7 countries and necessitate additional deliberation. This study highlights the importance of several key variables, including the precise identification of goals, the implementation of successful communication strategies, and the use of a comprehensive and inclusive set of indicators for monitoring and assessment purposes.

5.2. Policy Implications

Based on the findings from the analysis, these policies are recommended for policymakers within the understudy countries.

- As a first step, nations should establish targets for encouraging eco-friendly innovation through the broad use of environmentally friendly technologies. Authorities in the E7 can regulate clean manufacturing criteria based on industry specifications, allowing businesses to develop and deploy new green technology. Among the several types of hydropower dams, the earth-core rock-filled dam (ECRD) is the most carbon-efficient (CGD). The authorities can spur green innovation in ECRD by adopting it instead of CGD. Also, authorities can spur green innovation in the clean and sustainable energy sector by switching to a low-fossil-carbon energy grid. Moreover, E7 countries should implement industry-level regulations to encourage the widespread use of green technologies, which can lead to sector-wide environmentally friendly developments for avoidance purposes.

- Also, E7 economies would benefit from a decrease in their ecological friendliness if more money was put into environmentally friendly technology used in their manufacturing and processing of commodities. However, authorities could devise such enticing policies in order to increase investment in environmental green technology, resulting in a more sustainable environment in the E7 countries.
- The E7 nations should work closely with other nations to directly replicate and employ cutting-edge technologies, paying particular attention to the advantages of political globalization. Emissions should be avoided at the source; thus, the "pollute first, then treat" mentality and the path of economic growth at the expense of the environment must be reconsidered. Nevertheless, these countries need to consider the environmental impact and prioritize the development of technologies that promote ecological sustainability while enhancing their degree of technical innovation. Simultaneously, the phenomena of economic, political, and social globalization necessitate comprehensive deliberations on the difficulties of environmental safety. In this regard, it is imperative to use their distinctive technological capabilities to facilitate the advancement of technological innovation.
- The conservation of the natural environment is contingent upon the establishment of a robust governmental framework. The efficacy of governmental endeavors aimed at addressing ecological concerns is indicative of the condition of institutional frameworks. Clear institutional frameworks facilitate ecological responsibility by mediating conflicts and creating mutually beneficial outcomes. To effectively control emissions and determine how their practical integrity may be improved, authorities must focus on many aspects of governance and their interconnections.

5.3. Limitations of the study

The study focused exclusively on the E7 nations and conducted a limited evaluation of the impact of environmental green technology, technical innovation, and renewable energy utilization on CO2 emissions. While these factors are integral to understanding emissions dynamics, the research's narrow scope highlights the need for broader inquiries. Future studies should incorporate additional dimensions such as financial development, economic complexity, and human capital, which could provide a more comprehensive picture of the challenges and opportunities in reducing CO2 emissions.

To enhance the precision of policy implications, it would be advantageous to conduct evaluations at both the state and municipal levels. This localized approach can uncover unique regional challenges and successes, ultimately informing more effective policies. To ensure regulatory stability, the implementation of sustainable policies, and the advancement of research on SDGs, it is imperative to have trustworthy and comprehensive access to data. There exist multiple opportunities for additional research that can enhance our understanding of the extent to which the SDG can fulfil its commitments. By exploring these various elements, researchers can contribute to more effective strategies for environmental sustainability and economic development, paving the way for a more sustainable future.

Data availability
The data sets that support the findings of this study are openly available on request.

Declarations
The authors declare that the article contains no material previously published or authored by any other person except where due acknowledgment has been made.

Ethical approval and informed consent
This article does not contain any studies with human participants performed by any of the authors.

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