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Energy Transition and Institutional Quality in E-7 Economies: Unveiling Paths to Sustainable Development with CS-ARDL Analysis

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Abstract: The impact of energy consumption on sustainable development remains a critical global concern that is deeply influenced by the progress and effectiveness of the ongoing energy transition. The primary objective of this study is to examine the impact of the energy transition (ET) an institutional quality index (IQI) on sustainable development (SD), along with other control variables, including globalization (GLOB), trade openness (TO), gross domestic product per capita (GDP), and economic structure (EcoStru), in E-7 economies from 1990 to 2022. To fulfill this objective, we employ the cross-sectional autoregressive distributive lags (CS-ARDL) technique to tackle issues such as heteroscedasticity, cross-sectional dependence, and interaction across sections caused by variations in slope. Similarly, for the robustness analysis and based on the results of cointegration tests, we employed the Fully Modified Ordinary Least Square (FMOLS) and Canonical Cointegrating Regression (CCR) cointegration models. The empirical findings reveal that the ET, TO, and IQI significantly influence improving sustainable development in the E-7 countries. Meanwhile, GLOB and GDP have been shown to have a detrimental environmental impact. To move toward truly sustainable development, E-7 countries should emphasize the transition to renewable energy and reinforce institutional governance to lessen their dependence on fossil fuels.

Keywords: energy transition; globalization; sustainable development; institution quality; E-7 economies

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1. Introduction

In the era of Globalized World, there has been extensive discussion surrounding the concept of Sustainable Economic Growth. Pollution, including air, water, noise, and soil pollution, along with several other elements, has a significant impact on economic progress and overall well-being. Pollution has significant detrimental effects on human health and has substantial consequences for various natural resources. Additionally, pollution contributes to the increased occurrence of natural catastrophes due to the accelerated rate of climate change [1]. The depletion of the ozone layer, climate change, respiratory diseases, desertification, and deforestation have become significant global and national development and economic concerns worldwide. These issues have been extensively studied by Khurshid et al. [2], Naeem et al. [3], and Arfaoui et al. [4]. These environmental concerns have become multifaceted and require collaborative or unified actions from the worldwide community. The global sustainability threat cannot be effectively addressed by any individual nation in isolation [5,6].

Approximately 1.4 billion people across the world lack access to electricity, with 85% of them belonging to rural regions. If new regulations are not ratified, the global population without access to electricity might be reduced to 1.2 billion by 2030. According to the United Nations' 2023 [7] report on Sustainable Development Goal 7 (SDG 7), approximately 2.3 billion people relied on inefficient and polluting cooking systems in 2021. If current trends persist, nearly 1.9 billion people will still lack access to clean cooking solutions by 2030. The United Nations attributes around 90% of global CO_2 emissions and 75% of greenhouse gas emissions to fossil fuels. The reliance on fossil fuel use is now a critical measure of environmental decline, and the solution to this issue is the shift towards renewable energy sources [8]. In recent decades, the E-7 countries (India, Brazil, Russia, China, Indonesia, Turkey, and Mexico) have seen remarkable economic expansion. However, this progress has come at the cost of rising energy use and environmental deterioration. Based on data from British Petroleum Statistics, the E-7 nations account for around 42% of global energy consumption (refer to Figure 1) and contribute to 54% of carbon emissions worldwide (see Figure 2) [9].

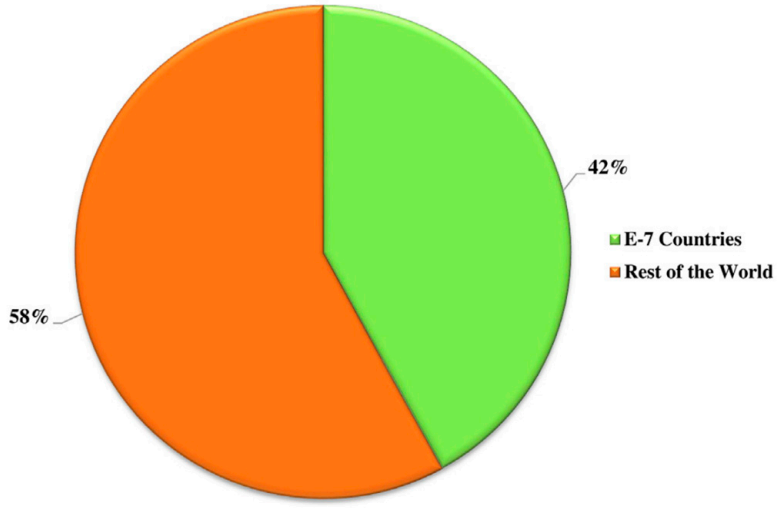


Figure 1. Share of E-7 countries in global energy consumption (Source: BP Statistical Review, 2022) [9].

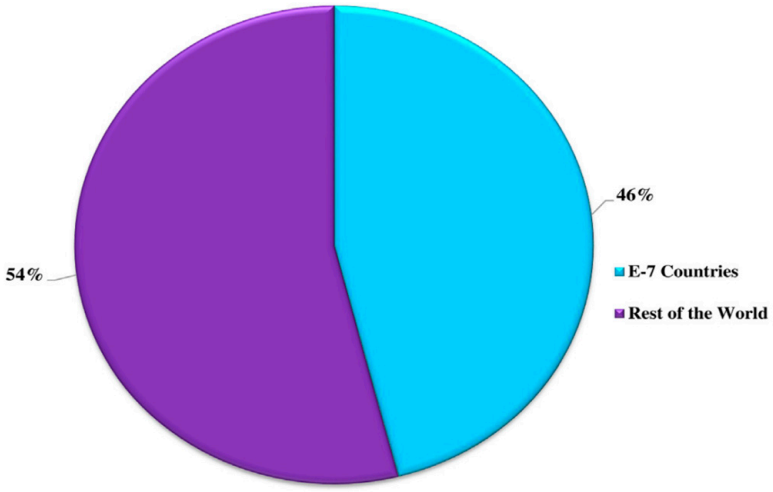


Figure 2. Share of E-7 countries in global CO_2 emissions (Source: BP Statistical Review, 2022) [9].

Experts and policymakers across E-7 nations have been striving to uphold environmental sustainability while minimizing any adverse impact on economic progress. Recent studies have identified several factors that can contribute to environmental sustainability at

present. These factors include energy transition [10], institutional quality, globalization [11], economic growth [12], and economic structure [13].

The term Energy transition refers to the shift from a reliance on fossil fuels to the adoption of renewable and zero-carbon energy sources, aimed at creating a more sustainable and low-emissions energy system [14]. Furthermore, world economies are actively implementing measures to decrease the utilization of fossil fuels, which are recognized as major contributors to CO_2 emissions. Instead, they are promoting the consumption of clean energy as a substitute for non-renewable energy sources. According to Taghizadeh-Hesary et al. [15], emerging economies, despite their diversity, have comparable challenges regarding energy sources. Some of the problems include the continued utilization of unrefined and primitive biomass in the energy composition. Countries worldwide are facing a lack of cheap energy availability for their expanding population. The electricity industry is facing challenges related to reforms, privatization, and financial unsustainability. Additionally, there is a fast-growing demand for energy in the transportation sector, which is heavily reliant on imported fossil fuels [16].

The efficacy and quality of institutions are closely associated with environmental viewpoints, as they have a dual role in both initiating and regulating the instructions for green technology [17]. The recent literature once again acknowledged the impact of the quality of institutions on the sustainable environment and showing that the efficacy of institutions is a crucial catalyst for environmental quality in a country. Consequently, to achieve higher levels of green growth, it is necessary to have a positive and effective performance of green institutions, as correctly pointed out by Ahmed et al. [18]. Additionally, institutions are important because they can further support positive levels of SEBD by proposing sustainable economic growth in a country [19]. The existing literature recognized that investing in renewable energy (RENE) is crucial to addressing the world's Environmental degradation [20]. Different studies have highlighted the importance of using renewable energy to transition from an economically damaging to an economically friendly economy. As it is generally assumed, the global economies are currently undergoing a new round of economic globalization. This concerns efforts to link these economies through trade and investment partnerships, including both bilateral and multilateral agreements. There is also a precious body of knowledge about the concept of globalization as a mobile variable in the contemporary environment of competition, as well as the results of its implementation in sustainable development concerning the countries of the Third World. Brief knowledge of the advancement of the globalization process and the likely impacts, either positive or negative, on sustainable development is essential [21]. As a result, the more recent period of globalization has been instrumental in the growth of the global economy.

Over the past decade, the environmental impacts of trade liberalization have dominated discussions on trade policy. Trade liberalization can affect environmental quality through two important channels: the composition effect and the scale impacts [22,23]. The scale effects draw attention to how the integration of trade affects economic activity. Increases in trade activity among the countries typically result in increases in transportation, consumption, and the creation of products and services, given that environmental expenses are typically associated with these activities. Thus, increased trade openness may promote economic growth at the expense of environmental quality. Furthermore, higher institution quality was strongly correlated with higher environmental quality [24,25].

It is commonly accepted that when economies grow, environmental deterioration should also tend to cost more. This is because increased economic activity often results in greater environmental difficulties. Therefore, sound political strategies that balance social justice, economic development, and environmental conservation should be put forth to identify and address these issues. Furthermore, one of the main factors supporting envi-

ronmental quality in a country would be well-designed and -implemented environmental legislation [5]. Strong institutions are essential for creating effective regulations that, when correctly implemented, can greatly reduce environmental problems on a global scale [26].

This study seeks to evaluate the growing significance of energy transition and institutional quality as factors influencing sustainable development in E-7 nations, which remains unexplored. The paper provides several key contributions from different viewpoints. The first step is to analyze the fundamental question: What is the significance of energy transition in the context of improving levels of sustainable development? To develop policies that promote long-term and sustainable human well-being, it is crucial to comprehend this link. An energy transition index was constructed to serve as a reliable measure of the progress made in the process of energy transition. In addition, we have created the sustainable development index, a comprehensive measure that encompasses the economic, social, and environmental dimensions of sustainability. Our model considers institutional quality as a predictor, acknowledging its pivotal role in shaping the environmental condition. Institutions serve as a supplement to policies, providing a framework for funding sustainability initiatives and ensuring compliance with environmental regulations inside an enterprise. Several interactional paths have been identified as being linked to changes in institutional quality. These pathways include the beneficial impacts of governance regulations, a reduction in corrupt behaviors, and the presence of renewable energy technology. To examine the dynamic relationship between energy transition, institutional quality, and other control variables, we utilize the cross-sectional autoregressive distributive lag (CS-ARDL) technique developed by Chudik and Pesaran in 2015. To achieve this objective, we will predict all the components that explain the long-term and short-term impacts of energy transition and institutional quality on sustainable development in E-7 nations from 1990 to 2022. The CS-ARDL approach is appropriate for implementation in this study because of its ability to address issues such as the existence of unit roots, endogeneity, non-zero slopes, and cross-sectional dependencies (CSDs), among other factors [27,28].

The subsequent sections of the article are organized in the following manner. Section 2 provides a comprehensive assessment and presentation of the pertinent content. Section 3 defines the data and presents the methodology employed for conducting the investigation. Section 4 presents the empirical assessment of the impact of sustainable development on energy transition in emerging 7 countries. The policy implications, outcome, and conclusion are provided in Section 5.

2. Materials and Methods

This section of our research consists of the previous empirical literature that investigated the nexuses among sustainable development, energy transition, globalization, trade openness, quality of institutions, and economic structure.

2.1. The Impact of the Energy Transition on Sustainable Development

Energy transition refers to the process of shifting from non-renewable energy sources to renewable energy sources. Initiating this movement is considered essential to provide a standardized process for certifying those who have access to sustainable contemporary energy [29]. Given the direct connection between environmental impacts and energy sources, it is important to avoid narrow-mindedness when considering the energy transition. This means not just focusing on specific technologies but also considering the components and repercussions of the entire energy system [30]. According to Hanif et al. [31], there has been a rise in global energy consumption and reliance on carbon-based fuels, increasing carbon emissions. Cantarero [29] highlighted that all countries in the Asian panel have comparable problems in their efforts to migrate to renewable energy sources, based on

the facts. According to Adam and Nsiah [32], emerging countries have reduced carbon dioxide (CO_2) emissions by implementing environmentally friendly innovations. Moreover, the utilization of renewable energy sources has been demonstrated in various studies conducted in emerging nations [33]; G7 countries, including Khan et al. [27]; and China and India, including Kirikkaleli [34] and Yang et al. [35], to contribute to the reduction of CO_2 emissions [36]. Furthermore, Arimah and Ebohon [37] have highlighted that Economic Transformation (ET) continues to be valuable in achieving Sustainable Development (SD) in African countries.

H1. *SD has been positively and significantly affected by the energy transition.*

2.2. The Impact of Globalization on Sustainable Development

Many people view globalization as widely regarded as key to economic expansion. Nevertheless, globalization significantly drives industrial development and the worldwide spread of fossil fuels, both of which contribute to environmental degradation. According to Ahmed et al. [38], environmental degradation is a significant consequence of globalization. The path to sustainability required for globalization might vary across nations, not necessarily following the same trajectory for all [39]. As countries pursue economic growth through globalization, environmental damages often arise alongside the expansion of trade, economic, and financial development. The rising demand for primary energy sources contributes to a deterioration in environmental quality, as indicated by Yilanci and Gorus [40]. Some studies find that globalization is often considered a significant catalyst for economic growth [41]. However, this economic growth may have negative consequences for environmental sustainability, as predicted by Asongu et al. [42].

H2. *Globalization negatively affects SD.*

2.3. The Impact of Institutional Quality on Sustainable Development

Strong institutional quality is one of the most central components of attaining SD. Azam et al. [43] highlight that efficient management of environmental resources is essential for SD. In exploring the association between the quality of institutions and sustainable development, it became evident that the strength of law, order, and the capacity of self-governance play a significant role, especially in the Middle East and North Africa. Additionally, control of corruption is critical in the Caribbean and Latin America. In the meantime, the superiority of the administration has a more distinct impact in Asia compared to other regions, as indicated by Hunjra et al. [44]. Furthermore, while discussing the link between SD and IQI, it is important to include emerging nations, namely, Asian economies. Shahbaz et al. [45] conducted a study that analyzed the impact of ecological footprints on both European and Asian economies. Their ultimate disclosure demonstrates that institutional, informal, and renewable energy have an impact on the ecological footprint. Additionally, informality has a beneficial influence on the ecological footprint in European nations, while it hurts the ecological footprint in rising Asian economies. An institution's quality has a significant impact on its environmental quality.

H3. *The quality of institutions has a significant impact on SD.*

2.4. The Impact of GDP on Sustainable Development

Typically, we measure a country's economic reputation through its GDP. However, GDP does not provide sufficient justification for the environmental and social costs and advantages. Adrangi et al. [46] examined a theory-driven model that investigates the

relationship between CO_2 emissions as an indicator of environmental damage and consumption as an indicator of GDP. The author analyzed the correlation between GDP and CO_2 emissions for nations with high, medium, and low levels of human development, as defined by the UN. Based on the research, nations with higher GDP are predominantly accountable for environmental degradation. However, countries with lower GDPs produce emissions at a higher proportionate rate compared to those with higher GDPs. Developing nations are primarily focused on enhancing the quality of life for their inhabitants. According to several reports, less developed economies comprise around 80% of the world population. We will incur the expense of environmental deterioration to enhance the standard of living for this substantial population [47]. Bekhet and Othman [48] found that growth in GDP has a detrimental effect on pollutants in the environment. Conversely, enhancing environmental quality relies on the focus directed towards renewable energy. Without a sustainable adaptation strategy, the impact of climate change could cause a GDP decrease of between 2 and 4% [49].

H4. *SD has a significant and negative impact on GDP.*

2.5. The Impact of Trade Openness on Sustainable Development

The effective trade liberalization policy over the past decade has been widely recognized as a catalyst for economic expansion in both developed and developing economies. According to Raghutla [50], countries like Brazil, China, India, Indonesia, Mexico, Russia, and Turkey are regarded as some of the most influential economies in the world in terms of foreign trade, predominantly in the context of rising economies. The influence of E-7 economies on global GDP increased from 1.1% in 1991 to 21.5% in 2017 [38]. Sachs [51] forecasts, based on data and statistics, that these emerging countries will emerge as global dominant nations by 2050. When discussing trade openness, it is important to acknowledge the influence it has on sustainable development. Ulhaq and Purwanto [52] observed that trade openness has had a considerable and beneficial effect on sustainable development in G7 nations. Both developed and developing nations have widely seen trade liberalization as a catalyst for economic growth during the past decade.

H5. *Trade openness has significant and positive causes.*

3. Data and Methodology

3.1. Conceptual Framework

The diagram in Figure 3 illustrates the impact of ET, IQI, EcoStru, GLOB, GDP, and TO on sustainable development. GLOB has a detrimental and substantial effect on SD, resulting in heightened economic activity, increased investment, enhanced trade, and more demand for natural resources and energy consumption. TO affects sustainable development through two channels: the composition effect and the scale effect. The scale effects refer to the amplification of commerce, transportation, manufacturing, and consumption to stimulate economic activity while simultaneously posing a threat to environmental sustainability. Composition effects, in the context of TO, pertain to the impact of this policy on a country's comparative advantage, industrial structure, and technical innovation. GDP expansion has a detrimental effect on sustainable development, increasing per capita income, a rise in aggregate demand and consumption, an enhancement of trade, and an escalation of environmental degradation. Ultimately, both IQI and economic structure exert a substantial and favorable influence on sustainable development. A nation with robust institutions will efficiently implement environmental policies, optimize the exploitation of natural resources, and enhance environmental quality. The economic structure may exert influence

on environmental quality through the presence of well-functioning institutions, such as a well-organized economic and financial system and an effective tax management system. These factors have a notable and beneficial effect on environmental quality.

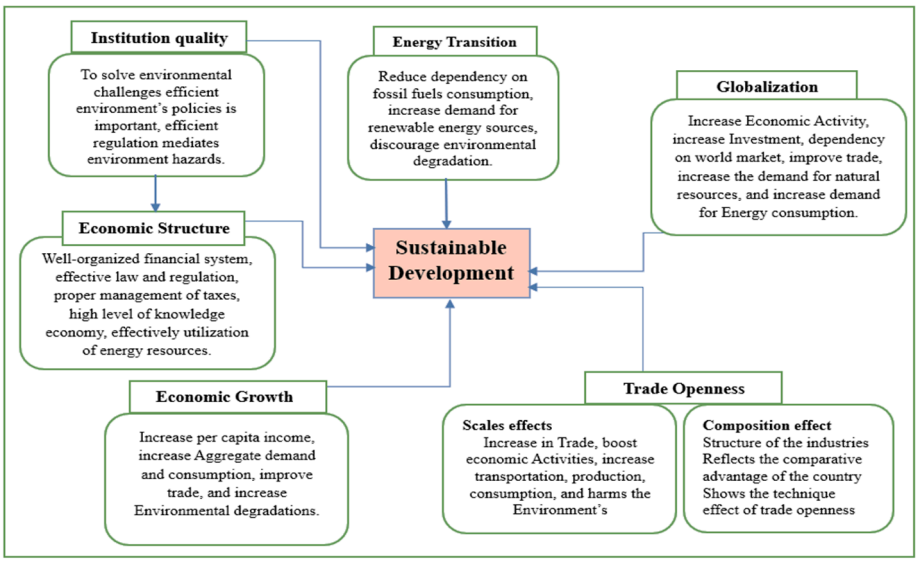


Figure 3. Conceptual framework.

3.2. Data and Measurement

3.2.1. Dependent Variable

Sustainable development is the dependent variable of this study. For the construction of SD, we have collected three different types of variables: the Economic variable GDP constant 2015, the social variable life expectancy at birth rate, and the environmental variable ecological footprint per capita. The construction of a sustainable development index has been followed from the previous study [53]. The data were collected on the mentioned variables from the World Development Indicators.

3.2.2. Independent Variables

Energy Transition Index

ET is one of the independent variables that we have included in our analysis. The usage of clean sources of energy is gradually replacing traditional, non-renewable energy sources, a phenomenon known as the energy shift. We have collected two sorts of variables—the percentages of total renewable energy and the percentages of total non-renewable power consumption—to construct the energy transition index. Additionally, we recorded information on three separate types of non-renewable energy sources: gas power generation, coal power generation, and oil power generation percentages. The results of the prior research by Taghizadeh-Hesary et al. [15] were used to develop the energy transition index. The research's Appendix A contains the variables' descriptions and definitions. You may find the WDI and IEA Statistics, which were used to compile the data, at https://www.iea.org/data-and-statistics/ (accessed on 17 July 2023). To compute the energy transition index, the following equation is used.

$$ET_{it} = \frac{Electricity\ production\ from\ renewable\ source\ \%\ of\ total_{it}}{Electricity\ production\ from\ coal\ +\ Oil\ +\ Gas\ source\ \%\ of\ total_{it}}$$

Quality of Institution Index

In this study, the institution's quality serves as the independent variable. Regulatory Quality, Political Stability, Control of Corruption, Government Effectiveness, Rule of Law,

and Voice and Accountability are the six pillars that make up the institution quality index. To show the nation's position relative to all the other nations in the aggregate indicator, these data were compiled using percentile ranking. The rank from lowest to highest is represented by a figure between 0 and 1. The ranking of the Percentile has been adjusted to reflect the fact that the composition of the nations included in the WGI has changed throughout time. For a description and definition, see the research's Appendix A. Each variable's data were collected using "The Worldwide Governance Indicators". Figure 4 reflects all the variables of IQI.

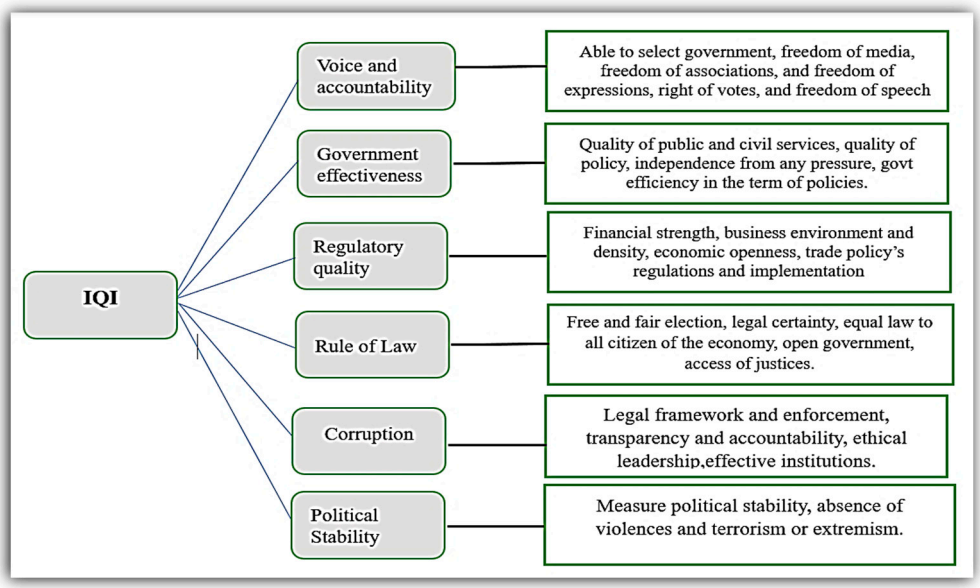


Figure 4. Institutional quality index.

Economic Structure Index

Economic structure refers to how the entire economy functions. On the other hand, economic freedom is the fundamental entitlement of each person to exercise control over their work and the property they possess. In economically free societies, individuals have the freedom to engage in employment, production, consumption, and investment. Economic freedom is assessed through a comprehensive evaluation of twelve factors, which can be classified into threemain groups: government size (including government spending, tax burden, and fiscal health); rule of law (encompassing property rights, government integrity, and judicial effectiveness); and regulatory efficiency (covering business freedom, labor freedom, and monetary freedom). Refer to the appendix part of the research for the explanation and definition of the indicators. Data were gathered for all variables using the heritage economic freedom index. The user provided a hyperlink to the website https://indexdotnet.azurewebsites.net/index/ (accessed on 17 July 2023).

Globalization

The research study's control variable is globalization. Economic development and environmental preservation are significantly influenced by globalization. Globalization has a significant impact on these two aspects. Globalization has considerably contributed to both opportunities and challenges in the context of economic development. Globalization is a method of enabling the economy to engage in the international trade market, encourage inward flows of FDI, and facilitate technological transmission [54]. The data were combined to create the Globalization Index from (https://kof.ethz.ch/en/forecasts-and-indicators/indicators/kof-globalisation-index.html, accessed on 19 July 2023).

Trade Openness

The study in question employs trade openness as a proxy variable for trade liberalization. The extent to which a country's commerce is open to the rest of the world is referred to as trade liberalization. Various indexes have been employed to quantify trade openness; however, we employed the conventional trade openness metric, which is equivalent to the aggregate of the import and export percentages of GDP [55]. The data were collected from the World Bank national accounts data and the OECD National Accounts data files.

GDP per Capita Income

The GDP per capita income was employed as a proxy variable for economic growth. The per capita income of GDP is calculated by dividing the gross domestic product by the midyear population. The data were collected in the form of GDP per capita constant 2015 from the World Development Indicators (WDIs).

Figure 5 illustrates the analytical process for the current research.

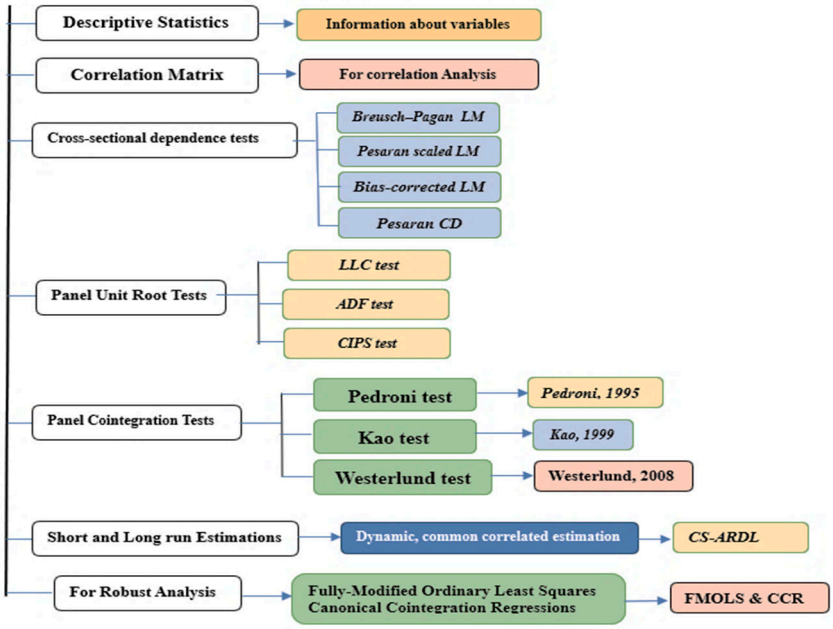


Figure 5. Analytical procedure [56–58].

3.3. Methodology

This study examines the influence of energy transition, globalization, trade openness, and GDP per capita on sustainable development in seven emerging nations. Additionally, it examines the impact of high-quality institutions and economic structure between the years 1990 and 2022. The primary objective of this study is to evaluate the possible impact of energy transition on sustainable development and to examine the influence of high-quality institutions and economic structure in the E-7 economies. Therefore, the following paradigm is suggested in this study:

$$SD = f\,(ET,\ IQI,\ GLOB,\ GDP,\ TO,\ EcoStru) \tag{1}$$

Equation (2) has been employed to measure the log-run relation of SD, which is the expanded form of Equation (1).

$$SDit = \gamma 0 + \gamma 1 ETit + \gamma 2 IQIit + \gamma 3 Globit + \gamma 4 GDPit + \gamma 5 TOit + \gamma 6 EcoStruit + \mu it \tag{2}$$

where, in the above equations, SD denotes sustainable development, ET denotes energy transition, IQI shows the institution's quality index, GLOB denotes the globalization index, GDP denotes GDP per capita, TO represents trade openness, and EchoStar represents the economic structure index. Moreover, *i* represents the entities, and *t* represents the periods (The process of energy transition enhances the efficiency of resources, hence promoting sustainable development. The energy shift is expected to have a favorable effect on sustainable development, $\left(\gamma 1 = \left(\frac{\partial SD}{\partial ET}\right) > 0\right)$; for globalization is projected to be negative, $\left(\gamma 2 = \left(\frac{\partial SD}{\partial GLOB}\right) < 0\right)$; GDP per capita is projected to be negative, $\left(\gamma 3 = \left(\frac{\partial SD}{\partial GDP}\right) < 0\right)$. For trade, openness is expected to be negative or positive $\left(\gamma 4 = \left(\frac{\partial SD}{\partial TO}\right) < 0\right)$; similarly, institution quality and the economic structure are projected to be positive $\left(\gamma 5 = \left(\frac{\partial SD}{\partial IQI}\right) > 0\right)$ and $\left(\gamma 6 = \left(\frac{\partial SD}{\partial EcoStru}\right) > 0\right)$.

3.4. Estimation Technique

This research employed cross-sectional dependence analysis (CSD). Also, the slope heterogeneity test proposed by Pesaran and Yamagata [59] was utilized in this current study. The equation can be written as:

$$\Delta_{SH}^{\sim} = (N)^{1/2}(2k)^{-1}\left(\frac{1}{N}s - k\right) \tag{3}$$

$$\Delta_{\mathrm{ASH}}^{\sim} = (\mathrm{N})^{1/2}\left[\frac{2\mathrm{k}(\mathrm{T}-\mathrm{K}-1}{\mathrm{T}+1}\right]^{-1/2}\left(\frac{1}{\mathrm{N}}\mathrm{S} - 2\mathrm{k}\right) \tag{4}$$

where ΔSH shows a delta tilde, and ΔASH shows an adjusted delta tilde.

Test for the unit root and cointegration analysis

For determining the stationarity of the research variables, this study employed the unit root test of the cross-sectionally augmented IPS, or CIPS, tests. In this study, a recommended unit root test was carried out to reduce any errors in any unit root test results. The CIPS equation may be expressed as:

$$\Delta W_{i,t} = \varphi_1 + \varphi_i Z_{i,t-1} + \varphi_i W_{t-1} + \sum_{l=0}^{p} \varphi_{il} \Delta W_{t-1} + \sum_{i=0}^{p} \Delta W_{i,t-1} + l_{i,t} \tag{5}$$

where W is the cross-sectional average.

$$W^{i,t} = \varphi^1 lnET^{i,t} + \varphi^2 lnGLOB^{i,t} + \varphi^3 lnGDP^{i,t} + \varphi^4 lnTO^{i,t} + \varphi^5 lnEcoStru^{i,t} + \varphi^6 lnIQI^{i,t} \tag{6}$$

The final CIPS statistic can be written as:

$$CIPS^{\sim} = \frac{1}{N}\sum_{i=1}^{n} CADF_i \tag{7}$$

Short- and Long run–result Estimation (CS-ARDL)

To conduct the final estimation of the research, we implemented a (CS-ARDL) model to investigate the long-term coefficient associations after conducting all necessary tests. The CS-ARDL is a renowned third-generation econometric model that considers the structural break and other factors to prevent the estimation from being biased. The cross-sectionally augmented autoregressive distributed lag model excels in comparison to other cointegration methods due to its assumptions regarding the control of slope heterogeneity, cross-sectional dependency, the issue of endogeneity, and structural breaks. The log-run estimation was

conducted using the CS-ARDL approach in this study. The equations of the CS-ARDL model can be expressed as follows:

$$C_{i,t} = \sum_{I=1}^{pc} \vartheta I, i\, C_{i,t-I} \; + \; \sum_{I=0}^{py} \delta I, i\, Y_{i,t-I} + \; \in_{i,t} \tag{8}$$

$$C_{i,t} = \sum_{I=i}^{pc} \vartheta_{I,i},\; C_{I,t-I} \; + \; \sum_{I=0}^{Py} \delta_{I,i}\, Y_{i,t-I} + \sum_{I=0}^{Pw} \sigma_I',\; IW_{t-I} \; \in_{i,t} \tag{9}$$

Equation (6) represents the basic equation that cannot deal with the problem of slope Heterogeneity and with cross-sectional dependency issues; therefore, the extended form of Equation (8) is Equation (9), which can deal with all these mentioned problems.

The average values are shown by $W_{t-I} = (C_{i,t-I}\, Y_{i,t-I})$, and where Pc, Py, and Pw reveal the lag values; $C_{i,t}$ indicates the research's dependent variable, sustainable development (SD); and Y_{it} explains the predictor variables of ET, GLOB, TO, IQI, GDP, and EcoStru. Meanwhile, W indicates the period dummy and its cross-sectional averages. Now the short- and long-run coefficient has been estimated by using an approach known as CS-ARDL.

The short- and long-run estimated coefficient equations are determined by:

$$\hat{\varphi} CS - ARDL_{,i} \; = \; \frac{\sum_{I=0}^{py} \hat{\delta_{I,i}}}{1 - \sum_{I=0}^{pc} \hat{\vartheta_{I,\,i}}} \tag{10}$$

Similarly, the mean groups are determined by:

$$\overline{\varphi_{MG}} = \sum_{i=1}^{N} \hat{\varphi}_i \tag{11}$$

Moreover, the above Equation (7) shows the short-term coefficient relationship among the research variables.

$$\Delta C_{i,t} \; = \vartheta_i [C_{i,\,t-1} - \theta_i Y_{i,t}] - \sum_{I=1}^{Pc-1} \vartheta_{I,i},\; \Delta_I\, C_{i,t-I} + \sum_{I=0}^{Py} \delta_{I,i}\, \Delta_I\, Y_{i,t} \; + \; \sum_{I=0}^{Pw} \acute{\sigma_i}, \overline{IW_t} + \epsilon_{i,t} \tag{12}$$

$$\hat{\gamma_i} = -\left(1 - \sum_{I=1}^{pc} \hat{\vartheta_{I,i}}\right)$$

$$(\varphi_(i\,)\,\hat{}\,(\varphi_(i\,)\,)\,\hat{}\,(\varphi_(i\,)\,)\,\hat{}\,(\varphi_(i\,)\,)\,\hat{}\,(\varphi_(i\,))\,\hat{}\,\hat{\varphi_i} \; = \frac{\sum_{I=1}^{Py} \hat{\delta_{I,i}}}{\hat{\gamma_i}}$$

$$\overline{\hat{\varphi_{MG}}} = \sum_{i=1}^{N} \hat{\varphi}_i$$

4. Results and Discussion

Table 1 presents the descriptive statistics of the research variable. Descriptive statistics are a crucial tool for conducting research and obtaining a comprehensive understanding of the variable. Based on the findings, the highest and lowest values of SD are 0 and 1, respectively, with an average value of 0.453. The energy transition has an average value of 0.394, with the lowest and highest values being 0 and 1.108, respectively. Institution quality is measured on a scale from 0 to 1, with the lowest value being 0 and the highest value being 1. On average, the value stands at 0.624. The average value of the economic structure is 56.63, with the lowest and highest values being 45.1 and 68.3, respectively. Globalization has an average value of 4.06, with a range of 3.45 to 4.29 at its lowest and highest points. Trade openness has a range of values, with the lowest being 2.71 and the highest being 4.70. On average, it has a value of 3.732. In a similar vein, the GDP per capita income varies between 8.63 and 17.56, averaging 11.77, with the highest and lowest values, respectively.

Table 2 presents the correlation among the study variables. Correlation analysis uncovers the linear relationship between variables. Based on the results, it is evident that

GLOB, GDP, TO, EcoStru, and IQI are positively associated with sustainable development, while ET has a negative association.

Table 1. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
SD	231	0.453	0.224	0.000	1.000
ET	231	0.394	0.310	0.035	1.108
IQI	231	0.624	0.229	0.000	1.000
EcoStru	231	56.633	5.305	45.100	68.300
GLOB	231	4.065	0.167	3.459	4.290
TO	231	3.732	0.388	2.718	4.706
GDP	231	11.777	2.494	8.637	17.565

Note: SD represents Sustainable Development, and ET, GLOB, GDP, TO, EcoStru, and IQI represent Energy transition, Globalization Index, GDP Per Capita, Trade Openness, Economic Structure Index, and Institutional Quality Index, respectively.

Table 2. Correlation matrix.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
SD	1						
ET	−0.080	1					
GLOB	0.385	−0.530	1				
GDP	0.420	0.031	0.162	1			
TO	0.207	−0.579	0.597	0.422	1		
EcoStru	0.458	−0.240	0.360	0.120	0.302	1	
IQI	0.002	0.321	−0.161	−0.489	−0.501	0.248	1

Table 3 presents the results of cross-sectional dependence tests. The findings have verified the presence of cross-sectional dependency in the model, highlighting the significance of employing second-generation panel unit root testing.

Table 3. Cross-sectional dependency tests.

Variables	Breusch–Pagan LM	Pesaran Scaled LM	Bias-Corrected Scaled LM	Pesaran CD
SD	244.820 ***	34.530 ***	34.420 ***	9.177 ***
ET	92.250 ***	10.990 ***	10.880 ***	4.130 ***
IQI	260.000 ***	36.880 ***	36.770 ***	−3.130 ***
EcoStru	92.250 ***	10.990 ***	10.880 ***	4.130 ***
GLOB	643.520 ***	96.050 ***	95.940 ***	25.360 ***
TO	170.720 ***	23.100 ***	22.990 ***	4.290 ***
GDP	53.200 ***	78.600 ***	78.500 ***	22.900 ***

*** shows significant at 1%.

Table 4 displays the second-generation panel's unit root tests for stationarity. The results show that SD, GLOB, TO, and GDP are stationary at I (0). Meanwhile, ET, IQI, and EcoStru remain stationary at l (1). So, it is concluded that the variables are mixed of stationarity.

To identify long-term relationships among the research variables, we utilized the panel's cointegration tests. Three different methods, namely, Pedroni [56], Kao [57], and Westerlund [58], were employed for conducting panel cointegration tests. The results of these tests are presented in Table 5. From the test results, the model demonstrates the presence of a cointegration association among the research variables.

Table 4. Results of panel unit root test.

Variables	Cross-Sectionally Augmented Im–Pesaran–Shin		Covariate Augmented Dickey–Fuller		Levin, Lin, and Chu	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
SD	−4.00 *	-	−3.43 *	-	−2.38 *	-
ET	-	−4.33 *	-	−8.40 *	−2.31 *	-
IQI	-	−3.98 *	-	−2.76 *	-	−8.54 *
EcoStru	-	−5.44 *	-	−4.81 *	-	−9.25 *
GLOB	−2.33 *	-	-	−7.08 *	−6.23 *	-
TO	-	−4.80 *	-	−8.23 *	-	−5.24 *
GDP	-	−4.01 *	-	−3.51 *	-	−7.02 *

Note: (*) Significant at the 10% level.

Table 5. Results of panel cointegration tests.

Cointegration Test	Statistics	*p*-Value
Padroni's test		
Phillips–Perron t	−11.483	0.000
Augmented Dickey–Fuller t	−9.338	0.000
Kao Test		
Modified Dickey–Fuller t	−10.327	0.000
Dickey–Fuller t	−8.268	0.000
Augmented Dickey–Fuller t	−5.251	0.000
Unadjusted modified Dickey–Fuller t	−17.381	0.000
Unadjusted Dickey–Fuller t	−9.364	0.000
Westerlund Test		
Variance Ratio	−1.841	0.033

The preliminary investigation indicates the presence of cross-sectional dependency, variation in slopes, and varying degrees of stationarity. The CS-ARDL method works well for our estimation study because it is stable even when there are cross-sectional dependence and different levels of stationarity [60]. This study employed the CS-ARDL approach to examine the long-term and short-term relationship between energy transition, globalization, GDP per capita, trade openness, quality of institutions, and economic structure and sustainable development in E-7 nations. Table 6 displays the observed results. The short-term estimations reveal that GLOB and GDP significantly negatively impact SD, while ET, IQI, TO, and EcoStru positively influence SD.

According to the long-run estimates, it is evident that a 1% rise in energy transition results in a 1.83% increase in SD over the long term. The transition to renewable energy sources fosters economic growth by creating environmentally friendly employment opportunities, encouraging investments in sustainable technologies, and improving energy security. These factors all work together to decrease greenhouse gas emissions and air pollution, which in turn improves public health and conserves natural resources. In addition, diversifying energy sources promotes technological innovation and competitiveness, which in turn supports efforts to adapt to and mitigate climate change. The existing literature [61,62] has shown a positive impact of energy transition on sustainable development. Furthermore, we verified Hypothesis 1.

Conversely, a negative and significant relationship between GLOB and SD were confirmed in both the short and long run. Our finding reveals that 1% of cross-border

integration, specifically, when considering its influence on SD, has resulted in a short-term reduction of 0.3% and an average long-term reduction of 1.2% in SD. The result followed by the previous literature that acknowledged the Pollution Heaven Hypothesis for E-7 nations [63–65]. Many individuals tend to view globalization as the primary factor contributing to economic expansion. However, it is crucial to consider a multitude of consequences that have the potential to endanger our natural resources. As global demand increases, the production of raw materials necessitates the depletion of forests, animals, and water supplies. Furthermore, globalization and its related phenomena, such as urban drift and industrial development, can have negative consequences, including environmental contamination. Meanwhile, the current study validates Hypothesis 2. These results are in line with what other research [66–68] has found about how globalization affects the environment through technological, size, and composition factors.

Table 6. CS-ARDL long-run estimates.

Variables	Coef.	Std. Error	Z	*p* > z	98% Conf. Interval	
ET	1.835	1.835	2.100	0.036 **	0.121	3.549
IQI	0.174	0.079	2.210	0.027 **	0.019	0.329
GLOB	−1.122	0.436	−2.570	0.010 **	−1.977	−0.268
GDP	−0.355	0.168	−2.110	0.035 **	−0.684	−0.026
TO	0.170	0.069	2.210	0.013 **	0.035	0.304
EcoStru	0.248	0.222	1.110	0.266	−0.189	−0.684
Short-run Estimates						
SD	−0.109	0.078	−1.390	0.164	−0.262	0.044
ET	1.829	0.766	2.390	0.017 **	0.328	3.329
IQI	0.174	0.081	2.140	0.033 **	0.014	0.033
GLOB	−1.196	0.437	−2.740	0.006 ***	−2.053	−0.340
GDP	−0.391	0.187	−2.080	0.037 **	−0.758	−0.023
TO	0.176	0.062	2.810	0.005 ***	0.053	0.298
EcoStru	0.001	0.138	0.000	0.996	−0.270	0.272
Coint-eq	−0.954	0.072	−13.260	0.000 ***	−1.095	−0.813
R-squared = 0.410		R-squared (MG) = 0.850		Prob > F = 0.00		
CD Statistic = −2.350		*p*-value = 0.019		Root MSE = 0.06		

Note: (**) Significant at the 5%; (***) Significant at the 1%.

Remarkably, research has discovered that, over an extended period, there exists a significant and beneficial impact of IQI on SD. Robust institutions are essential for the implementation and enforcement of effective environmental legislation, which aims to reduce pollution levels and promote responsible resource utilization. These practices have significant consequences for resource use, including water, fisheries, and forestry, as well as for minimizing pollution, especially through differentiated and efficient resource usage. Empirical research suggests that a slight enhancement in institutional quality reduces the SD by 0.17 percent in the short term and 0.176 percent in the long term. These findings corroborate prior research [69–71] demonstrating the role of institutions in enhancing a nation's welfare and promoting developmentalism, leading to enhanced economic growth. This study validates Hypothesis 3: institutions significantly improve sustainable development.

The relationship between GDP and SD is strongly negative. Structural shifts in the economy influence the relationship between economic growth and environmental degradation. The shift from an agricultural to an industrial, and eventually a service-driven, economy frequently results in higher energy consumption and subsequent environmental consequences [72]. Increased GDP can have negative effects on sustainable development, as it can contribute to overconsumption and environmental degradation. Higher economic

activity often leads to increased pollution levels and resource depletion. In addition, economic growth can worsen income inequality by hiding differences in access to resources and quality of life. The focus on immediate economic benefits may sometimes overshadow the importance of long-term sustainability, resulting in increased greenhouse gas emissions and environmental difficulties. This study supported Hypothesis 4: there is a negative association between GDP per capita and sustainable development.

TO has a positive correlation with SD. In the short run, a 1% increase in trade openness leads to a 0.17% increase in sustainable development, while in the long run, the increase is 0.176%. Nations that embrace trade enjoy the advantages of importing eco-friendly technologies and energy resources. This increases renewable energy availability and aids in the transition to sustainable energy consumption throughout the country. Our finding supports Hypothesis 5. The finding of our study aligns with prior research [73–76] that emphasizes the significance of trade in facilitating the spread of green technologies and encouraging the adoption of renewable energy.

Table 7 shows the robustness analysis of our findings after CS-ARDL and confirms the cointegration among the variables we have employed with two cointegration models, namely, the Fully Modified Ordinary Least Square (FMOLS) and Canonical Cointegration Regression (CCR) Models, which provide strong evidence of the stability of our findings. The existing literature widely employed the FMOLS and CCR models as the robustness check of the CS-ARDL model for different continents and regions, including [69,77–80], while evaluating the impact of energy consumption on Environmental sustainability. The result of both models is consistent with the finding of the CS-ARDL model. The reported table shows there is a significant and positive relationship between sustainable development and energy transitions, indicating the results of both models. The increase of 1% in energy transition leads to an increase of 0.7% and 1% in sustainable development. The coefficient of institutional quality shows a positive and significant relationship between institutional quality and sustainable development for E-7 economies. Conversely, globalization shows a significant and negative relationship with sustainable development. Meanwhile, a significant and positive relationship was found between trade openness and sustainable development. The overall result from FMOLS and CCR cointegration results are consistent with the result of CS-ARDL models, confirming the robustness of our results.

Table 7. FMOLS and conical cointegration model.

Variables	(FMOLS Result)	(CCR Result)
	SD	SD
ET	0.70 ***	1.17 ***
	(2.56)	(2.25)
IQI	0.11 ***	0.12 ***
	(10.74)	(5.30)
lgGLOB	−0.53 ***	−0.48 ***
	(−21.58)	(−9.80)
lgGDP	−0.01	−0.02
	(−0.52)	(−0.03)
lgTO	0.13 ***	0.11 ***
	(16.79)	(7.59)
EconStr	−0.27 ***	−0.26 ***
	(−29.41)	(−14.41)

Note: *t*-stat in parentheses, *** $p < 0.01$.

5. Conclusions and Policy Recommendation

This study examines the relationship between energy transition, globalization, trade openness, GDP per capita, institutional quality, and economic structure and sustainable development in the E-7 nations from 1990 to 2022. A series of preliminary statistical tests were conducted before estimation. Cross-dependency test results confirm the presence of cross-sectional dependence within the panel dataset. Panel unit root tests reveal a mix of stationarity at both the I (0) and I (1) levels, justifying the application of panel cointegration techniques. The results from various panel cointegration tests confirm the existence of a long-run relationship among the study variables. To estimate both short- and long-run effects, this study employs the CS-ARDL, FMOLS, and CCR approaches.

Empirical findings from the CS-ARDL model indicate a positive and significant impact of energy transition, trade openness, and institutional quality on sustainable development in both the short and long run. Conversely, globalization and GDP per capita exhibit a negative association with sustainable development. The robustness of these results is confirmed through FMOLS and CCR models, both of which validate the long-run cointegration among variables. Specifically, a 1% increase in energy transition leads to a 0.7% to 1% improvement in sustainable development across these models. Institutional quality also demonstrates a strong and positive impact, while trade openness fosters sustainability. Meanwhile, globalization exerts a negative influence on sustainable development.

The study's findings offer valuable insights for policymakers in E-7 nations, emphasizing the need for a structured transition toward renewable energy sources to achieve long-term environmental and economic sustainability. Strengthening institutional frameworks, implementing sustainable trade policies, and enhancing regulatory mechanisms are essential for mitigating the adverse effects of globalization on sustainable development. Additionally, robust policies action is essential for E-7 economies; incentivizing clean technology in high-emissions sectors, empowering environmental governance, and promoting green trade strategies can enhance long-term sustainable development. Moreover, regulating trade openness and applying sector-specific green taxation, such as carbon levies in Brazil's agribusiness or India's construction sector, can mitigate the environmental tradeoff between globalization and growth. Economic diversification, with a focus on renewable energy, green technologies, and sustainable agriculture, is vital for fostering long-term sustainability. The overall robustness of these findings underscores the critical role of institutional quality and energy transitions in shaping the sustainable development trajectory of E-7 economies.

6. Limitations and the Way Forward of the Study

This study provides meaningful insights into the factors influencing sustainable development in E-7 economies. However, this study has several limitations. Firstly, this study relies on macro-level panel data, which may not overlook country-specific institutions, environmental, and sectoral influence on environmental effects. Secondly, although the CS-ARDL model is well-suited to address issues like cross-sectional dependence and heterogeneity, it is unable to explore the spatial effects. Thirdly, we have incorporated both the institutional quality and economic freedom index to evaluate their impact on environments; however, the E-government development index also plays a significant role in mitigating sustainable development worldwide, and it remains unexplored in E-7 economies. So, a future study would be helpful from the policy perspective while incorporating the role of E-government in environmental sustainability.

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Appendix A

Table A1. Institutional quality index construction.

Variables	Unit	Definition
Control of Corruption	0 to 1	*It reflects how much people perceive the misuse of public power for personal gain, whether through minor act of bribery or significant corruption.*
Government *Effectiveness*	0 to 1	*It measures how people view the quality of public services and civil services, emphasizing their independence from any political pressure and the effectiveness of policymaking.*
Political Stability	0 to 1	*It assesses the public's perceptions of the likelihood of the chance of political instability and the potential for politically motivated violence, including terrorism.*
Regulatory Quality	0 to 1	*It reflects how the public views the government's capacity to design and enforce effective policies and regulations that foster both private and public sector growth.*
Rule of Law	0 to 1	*It evaluates how people trust and follow societal rules, focusing on areas like contract enforcement, protection of property rights, and the effectiveness of the police and courts in dealing with crime and violence.*
Voice and accountability	0 to 1	*It reflects how people perceive their ability to participate in choosing their government, as well as their freedoms of expression, association, and access to a free media.*

Note: the data were accessed from World Governance Indicators, where 0 indicates low, and 1 indicates high.

Table A2. Sustainable development index construction.

Variables	Unit	Definition
Annual Growth	**Percent (%)**	*The annual growth rate of GDP, calculated employing market prices and using constant local currency.*
Life expectancy at birth	**Year**	*Life expectancy at birth estimates how long the average number of newborns are likely to live, assuming that the current rate of mortality remains the same at the time of birth.*
CO_2 emissions	***(kg per PPP $ of GDP)***	*The emissions of CO_2 are generated from the burning of fossils. These emissions include the CO_2 released during the use of solid, liquid, and gas fuels, as well as from gas spreading.*

Note: the data were gathered from World Development Indicators, and for the construction of the index, the following study was followed: ([16]).

Table A3. Energy transition index construction.

Variables	Unit	Definition
Renewable electricity output	***(% of total electricity)***	*Renewable electricity is the share of electricity generated by renewable power plants in the total electricity generated by all types of plants.*
Oil source of electricity production	***(% of total)***	*Referred to the electricity generation from Oil, including crude oil and petroleum.*
Natural gas source of electricity	***(% of total)***	*Shows the electricity generation from gas, specifically, from natural gas, excluding natural gas in liquid form.*
Electricity production from coal sources	***(% of total)***	*Referred to the electricity production from coal sources including all type of coal and fossils fuels.*

Note: the data were accessed from https://www.iea.org/data-and-statistics/ (accessed on 17 July 2023) and followed the study [15].

Table A4. Economic structure index construction.

Variables	Unit	Definition
Property Right	**(0 to 100)**	*Entirely dedicated to the measurement of intellectual and physical property rights.*
Government Integrity	**(0 to 100)**	*Measures the political power continuously in the public interest, independently of private interest.*
Judicial Effectiveness	**(0 to 100)**	*Measures the well-functioning of the civil justice system, protect the rights of all citizens of the country.*
Tax burden	**(0 to 100)**	*Measures the amount of tax paid by a person, company, or country in a specified period as a proportion of total income in that period.*
Government Spanding	**(0 to 100)**	*Government spending refers to money spent by the public sector on the acquisition of goods and the provision of services.*
Fiscal Health	**(0 to 100)**	*A government is considered fiscally healthy if its resources meet its obligations.*
Business Freedom	**(0 to 100)**	*The freedom of initiative in which the entrepreneur manifests his legal will according to his interests.*
Labor Freedom	**(0 to 100)**	*Measures the fundamental right of every human to control his or her own labor and property.*
Monetary Freedom	**(0 to 100)**	*Measures people are free to choose what sort of money they will keep on hand or accept from others.*
Trade Freedom	**(0 to 100)**	*Measures how much country's trade is free to the rest of the world.*
Investment Freedom	**(0 to 100)**	*Measures if individuals are free to work, produce, consume, and invest in anything they want, but according to the rules and regulations.*
Financial Freedom	**(0 to 100)**	*Measures country's complete control over finances, allowing it to make choices based on its desires.*

Note: the data were accessed from the Heritage Economic Freedom Index (https://indexdotnet.azurewebsites.net/index/, accessed on 17 July 2023).

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